Eastern Research Group, Inc.

Evaluation of Ontario *Drive Clean* Program

FINAL REPORT

Prepared for:

Ontario Ministry of the Environment

July 18, 2005

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EVALUATION OF ONTARIO *DRIVE CLEAN* PROGRAM

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Prepared for:

Ontario Ministry of the Environment

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1.0 Introduction

Smog is a serious health issue in Ontario, particularly in the southern portion of the province. A significant component of smog is ground-level ozone, which is formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) chemically react in the presence of sunlight. Another major component of smog is fine particulate matter ($PM_{2.5}$), which is typically defined as those particles with an aerodynamic diameter of 2.5 micrometers (2.5 µm) or less. In addition to the formation of ground-level ozone, PM and NO_x also have direct health impacts.

Motor vehicles (i.e., passenger cars, light-duty trucks, and heavy-duty trucks) have been identified as the largest source of NO_x and VOC emissions in Ontario. Motor vehicles have been identified as a significant source of $PM_{2.5}$, as well. Motor vehicles also emit significant quantities of other pollutants that adversely affect air quality (e.g., carbon monoxide [CO] and benzene) and climate change gases (e.g. carbon dioxide [CO_2]).[1]

To reduce motor vehicle emissions and their associated health and air quality effects, Ontario has adopted a three-pronged approach focusing on cleaner fuels, cleaner vehicles, and improved vehicle maintenance. The cleaner fuels and cleaner vehicles aspects are targeted by the national implementation of adjusted fuel formulations and new vehicle standards. Ontario's *Drive Clean* program is an important policy to reduce in-use emissions from motor vehicles.

The *Drive Clean* Office (DCO) (of the Ontario Ministry of the Environment [MOE]) has conducted several evaluations of the *Drive Clean* program; the MOE contracted with ERG to conduct the current evaluation of the program. A brief description of the *Drive Clean* program and an overview of ERG's program evaluation are provided below.

1.1 *Drive Clean* Program Background

Drive Clean is Ontario's mandatory vehicle emissions inspection and maintenance (I/M) program for light- and heavy-duty vehicles. The *Drive Clean* program began in 1999. Since its inception, several modifications have been made to the program regarding the applicable geographical area, repair cost limits, and maximum allowable emission cutpoints.

[1] Although motor vehicles are significant sources of CO_2, recent analyses indicate that inspection and maintenance programs like Drive Clean do not provide clear reductions in this pollutant. For this reason CO_2 is not addressed in detail in this analysis.

The purpose of the *Drive Clean* program is to test vehicle emissions in order to identify high-emitting vehicles with missing, broken, or malfunctioning emission controls. Once these vehicles are identified, the program strives to ensure that effective and durable repairs are performed on them, with the ultimate goal of reducing on-road emissions. The key objectives of the program include:

- Helping Ontario meet its air quality objectives and commitments by minimizing vehicle emissions.
- Ensuring that vehicles in the program area are meeting provincial emissions standards.
- Encouraging good vehicle maintenance practices among vehicle owners in the program area.

The program is committed to continuous improvement, and its design includes a set of four primary performance objectives:

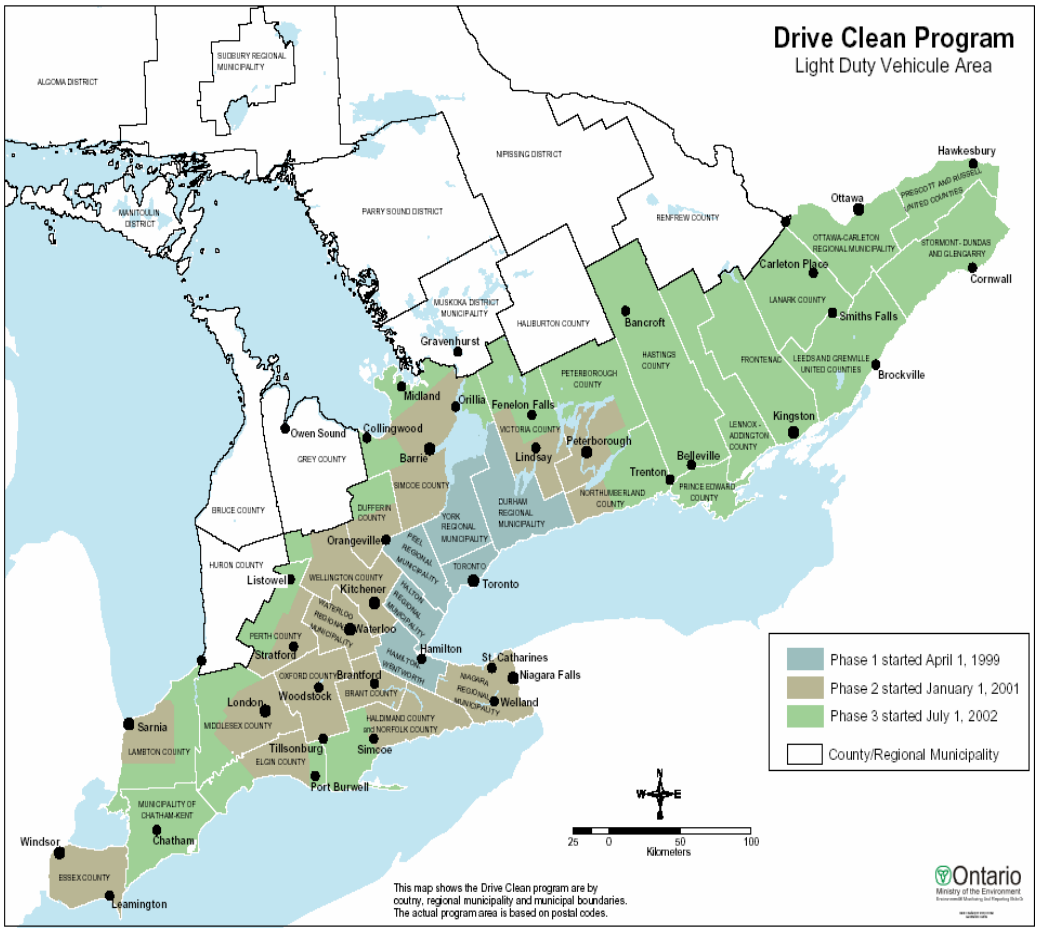
1) Effectively reduce emissions of smog-causing pollutants including NO_x, VOCs, and particulate matter (PM).
2) High degree of public acceptance.
3) Revenue neutrality over the life span of the program with full-cost recovery via testing and accreditation fees.
4) Business integrity. (The program is designed to achieve the highest standard of compliance with the Performance Contract at *Drive Clean* facilities.)

Table 1-1 summarizes the current design of the *Drive Clean* program; Figure 1-1 shows the areas of Ontario covered by the program.

Table 1-1. *Drive Clean* Program Design Features

Key Feature	Light-duty Vehicles (Passenger Cars)	Heavy-duty Vehicles (Trucks and Buses)
Program Area(s) and Phase-In	1999: GTA/Hamilton-Wentworth. 2001: Designated urban areas & commuter zones (south-central and southwest). 2002: Southern Ontario Smog Zone (from Windsor to Ottawa).	1999: Diesel (entire Ontario province); Non-Diesel (same phases as passenger cars).
Vehicle Types	All types of on-road passenger vehicles (with a GVWR of 4500 kg or less), except: • Vehicles more than 19 model years old. • Farm-plated vehicles. • Motorcycles.	All on-road vehicles with a GVWR over 4500 kg, except designated historic vehicles.
Model Years Included	Registration renewal: Vehicles more than three and less than 20 model years old. Resale: Vehicles more than the current model year and less than 20 model years old.	Registration renewal: Vehicles more than three model years old. Resale: Vehicles more than the current model year old.
Inspection Frequency	Biennial, and at transfer of ownership/resale.	Annual (except for vehicles that earn an incentive, which qualifies them for biennial testing) and at transfer of ownership/resale.
Inspection Fee	$35 maximum, excluding GST.	Market price on all tests.
Re-Inspection Fee	$17.50 maximum, excluding GST (allow only two retests at $17.50).	Market price on all tests.
Inspection Procedures	• ASM 2525 dynamometer and curb idle test for light-duty non-diesel vehicles. • Two-speed idle test for vehicles that cannot be tested on the dynamometer. • Visual test for diesel vehicles.	• Snap-acceleration smoke opacity inspection procedure of the Society of Automotive Engineers (SAE J1667) for diesel vehicles. • Two-speed idle inspection for non-diesel HDVs.
Emissions Standards	The emissions standards are set forth in the *Drive Clean* Guide referred to in Regulation 361/98. Tighter standards phased in starting 2003 and again in 2005.	The emissions standards are set forth in the *Drive Clean* Guide referred to in Regulation 361/98. Tighter standards implemented on April 1, 2004 and again on April 1, 2005.
Program Infrastructure	The program is delivered through a decentralized network of test-only, test and repair, and repair-only locations.	The program is delivered through a decentralized network of test-only stations, some of which provide mobile testing for diesel-powered vehicles.
Repair Cost Limits (RCL)	$450 RCL (only for registration renewals).	No RCL
Compliance Program	*Drive Clean* includes overt and covert audits of *Drive Clean* Facilities (DCFs) to ensure compliance with program rules. Each year, *Drive Clean* conducts about 4,500 audits of accredited *Drive Clean* facilities. *Drive Clean* suspends or terminates facilities for noncompliance with program rules.	
Complaint Response/Dispute Resolution Mechanism	Three levels of dispute resolution are provided. The first level involves the Call Center and the DCF. The second level involves the QA/QC Contractor who responds to referrals from the Call Center including requests for referee tests. The third level is handled by the Province	
On-Road Monitoring	Roadside inspection for emissions standards and required emissions control devices.	
Communications	The program has unique logos and conducts ongoing outreach to vehicle owners and the public.	

Figure 1-1. *Drive Clean* Light-duty Program Area as of January 1, 2005, in the Southern Ontario Smog Zone



1.2 Purpose and Objectives of the *Drive Clean* Program Review

The purposes and objectives of the *Drive Clean* program review study include:

- Evaluation of the *Drive Clean* program's current and future environmental, economic, and social costs and benefits.
- Evaluation of the *Drive Clean* program's effectiveness in achieving its goals and objectives, including the strengths and weaknesses of its program design features and parameters.
- Benchmarking of the *Drive Clean* program's results relative to other decentralized I/M programs.
- Development of future program improvement options.
- Assessment of future program improvement options leading to recommendations for maximizing the program's effectiveness.

These purposes and objectives were met through the implementation of the methodology described in Section 1.3.

1.3 Methodology

The methodology used in this study, originally outlined in the study work plan, includes four main tasks:

- Summarize previous findings.
- Evaluate costs and benefits of the *Drive Clean* program.
- Evaluate the program's effectiveness.
- Develop and assess program improvement options.

For Task 1, there was an overall review of all relevant background materials on Ontario air quality, overall emissions, and contribution of vehicle emissions. This was followed by an assessment and review of both previous and current estimates of emission reductions attributable to the program. In addition, future emission reductions will be projected using MOBILE6.2C.

Task 2 focused on an evaluation of programs costs and benefits. Average costs were estimated for consumers (e.g., test and repair costs), government (e.g., administrative costs), and industry (e.g., test equipment, salary and wage costs). Then the cost-effectiveness of the *Drive Clean* program was estimated using emission reduction benefits.

Task 3 evaluated the program effectiveness and specifically how certain aspects of the program impact the effectiveness. These aspects included the following:

- Vehicle coverage;
- Test method;
- Test frequency;
- Cutpoints;
- Repair effectiveness;
- Conditional passes;
- DCF compliance and test fraud;
- Registration fraud;
- On-road enforcement;

- Public acceptance; and
- Revenue neutrality.

Finally, Task 4 involved the development and assessment of program options. Some identified improvement options that were assessed and analyzed included:

- Improved identification of high-emitters;
- Reduced test, repair, and registration fraud;
- Improved repair effectiveness;
- Improved program cost-effectiveness; and
- Reduced emissions from sources outside of program.

The projected effectiveness of each option was analyzed using MOBILE6.2C. In conjunction with this, a matrix was prepared that summarized the qualitative assessment of each option in terms of, costs, cost-effectiveness, effectiveness in reducing emissions, general health impacts, and social impacts.

2.0 Overview of Air Quality, Emissions, and Related Health Issues in Ontario

Ontario faces considerable challenges related to air quality and its associated health effects. A brief description of Ontario's current air quality situation and trends is presented below, as well as a discussion of the health effects of air pollution in Ontario. The relative importance of on-road source emissions is also presented. Finally, the section briefly discusses federal and provincial regulations and other initiatives aimed at reducing mobile source emissions.

2.1 Current Air Quality Situation in Ontario, and Southern Ontario

The ambient air quality in Ontario is measured by one of the most comprehensive air monitoring systems in North America (MOE, 2004a). This air monitoring network includes more than 40 ambient monitoring sites located throughout the province that measure ambient concentrations of six contaminants: ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), and total reduced sulphur compounds (TRS). In addition, the ministry reports volatile organic compounds (VOCs) data from sites across Ontario operated by Environment Canada.

Currently, the following Canada-wide Standards (CWS) and provincial ambient air quality criteria (AAQC) are applicable in Ontario:

- O_3 – 1-hour provincial AAQC (80 ppb), 8-hour CWS (65 ppb);
- $PM_{2.5}$ – 24-hour CWS (30 µg/m^3);
- NO_2 – 1-hour provincial AAQC (200 ppb), 24-hour provincial AAQC (100 ppb);
- CO – 1-hour provincial AAQC (30 ppm), 8-hour provincial AAQC (13 ppm);
- SO_2 – 1-hour provincial AAQC (250 ppb), 24-hour provincial AAQC (100 ppb), annual provincial AAQC (20 ppb); and
- TRS – 1-hour provincial AAQC (27 ppb).

In general, Ontario meets the national/provincial ambient air quality objectives and criteria for NO_2, CO, and SO_2. Widespread exceedances of the ozone and particulate matter standards and criteria occur throughout the province, while there are only some very localized infrequent exceedances of the TRS criterion.

Ozone

Ground-level ozone (O_3) was monitored at 41 sites during 2003. Data from 39 of these sites were reported in the Ontario Ministry of the Environment (MOE) Air Quality in Ontario Report 2003 (MOE, 2004a). The annual mean concentration for 2003 ranged from a maximum for 34.9 parts per billion (ppb) at the Port Stanley site to a minimum of 18.7 ppb at the Toronto West site. The highest one-hour concentration (149 ppb) was measured at the Belleville site.

With the exception of the Thunder Bay site on the shore of Lake Superior, all of the other 38 monitoring sites exceeded Ontario's one-hour ambient air quality criterion (AAQC) of 80 ppb. The largest number of exceedances occurred at sites on the north shore of Lake Erie (e.g., 138 at Port Stanley and 118 at Simcoe).

In general, ozone levels in southern Ontario decrease from southwest to northeast. Significant amounts of Ontario's ozone levels during widespread smog episodes are due to long-range transport of ozone and its precursors (nitrogen oxides (NO_x) and VOCs) from neighboring U.S. states. The U.S. contribution, excluding background levels, is expected to be as much as 90 percent in those areas in close proximity to the U.S. (i.e., northern shores of Lake Erie, eastern shores of Lake Huron and Georgian Bay, and the Windsor/Detroit area) (MOE, 2004a).

Fine Particulate Matter

Fine particulate matter, or $PM_{2.5}$ (particulate matter with an aerodynamic diameter of 2.5 micrometers or less), was measured at 37 ambient monitoring sites of which 27 provided sufficient data to be reported (MOE, 2004a). The annual mean for 2003 ranged from a maximum of 11.9 micrograms per cubic meter ($\mu g/m^3$) at the Sarnia site to a minimum of 5.5 $\mu g/m^3$ at the North Bay site. The highest 24-hour concentration (58.9 $\mu g/m^3$) was also recorded at Sarnia.

All 27 of the reported monitoring sites exceeded the $PM_{2.5}$ reference level of 30 $\mu g/m^3$ for a 24-hour period (based on the Canada-wide Standard (CWS)) at least once. The 98^{th} percentile $PM_{2.5}$ daily average exceeded 30 $\mu g/m^3$ at four monitoring stations: Oakville, Hamilton Downtown, London, and Mississauga.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) was monitored at 29 sites during 2003, of which 19 provided sufficient data to be reported in the summary report (MOE, 2004a). The highest NO_2 concentrations were measured in urban and industrialized areas. The highest annual mean (26.6 ppb) was measured at the Etobicoke South site in Toronto, while the highest 24-hour

concentration (71 ppb) and the highest one-hour concentration (119 ppb) were both measured at the Toronto West site. However, none of the monitoring sites exceeded the provincial 24-hour criterion of 100 ppb or the one-hour criterion of 200 ppb.

Carbon Monoxide

Carbon monoxide (CO) was monitored at 19 sites during 2003. Thirteen of these sites provided sufficient data to be reported in the summary report (MOE, 2004a). Typically, the highest CO measurements were recorded in large urban centers as a result of vehicle emissions. The highest annual mean (0.68 parts per million (ppm)) was measured at the Brampton monitoring site. The highest one-hour maximum concentration (7.1 ppm) was measured at the Newmarket site, while the highest 8-hour concentration (3.3 ppm) was recorded at the Mississauga site. However, none of the monitoring sites exceeded the provincial one-hour criterion of 30 ppm or the 8-hour criterion of 13 ppm in 2003. In fact, these two criteria have not been exceeded at any sites in Ontario since 1991.

Sulphur Dioxide

Sulphur dioxide (SO_2) was monitored at 24 sites in 2003. Eighteen of these sites provided sufficient data to be reported in the summary report (MOE, 2004a). The highest annual mean (7.1 ppb) and 24-hour maximum concentration (63 ppb) were recorded at the Sarnia site, while the Sudbury site located at Science North recorded the highest one-hour concentration (226 ppb). However, none of the provincial criteria (i.e., 250 ppb for one-hour, 100 ppb for 24-hour and 20 ppb for annual mean) were exceeded during 2003 at any monitoring sites.

Total Reduced Sulphur Compounds

Total reduced sulphur (TRS) compounds were monitored at eight sites in 2003, of which four provided sufficient data to be reported in the summary report (MOE, 2004a). The highest TRS annual mean (0.7 ppb) was measured at the Sarnia site, while the highest maximum one-hour maximum concentration (74 ppb) was recorded at Oakville. Oakville also had the highest number of hours (3) over the TRS AAQC of 27 ppb.

VOC Air Toxics

A total of 143 VOCs were measured at eight sites across Ontario during 2003. Some of the more significant VOCs measured include aromatic hydrocarbons (e.g., benzene, toluene, xylene) and halogenated compounds (1,1,1-trichloroethane, carbon tetrachloride, and

tetrachloroethylene). The annual mean concentrations in 2003 for benzene, toluene, and xylene were 1.05 µg/m^3, 2.55 µg/m^3, and 1.35 µg/m^3, respectively.

Air Quality Index

The Air Quality Index (AQI) network provides near real-time air quality information to the public from across the province. Every hour, the concentrations of the pollutants that have adverse effects on human health and the environment (i.e., O_3, NO_2, SO_2, $PM_{2.5}$, CO, and TRS) are converted into a sub-index. For a given site, the hourly AQI reading is the highest sub-index across the six pollutants. The AQI has five categories: Very Good (AQI values 0-15), Good (AQI values 16-31), Moderate (AQI values 32-49), Poor (AQI values 50-99), and Very Poor (AQI values 100+). On average, the AQI sites in 2003 reported air quality in the good and very good categories approximately 90 percent of the time and the moderate to poor air quality approximately 10 percent of the time. The air quality in the very good to good categories recorded at individual sites ranged from approximately 83 per cent at Port Stanley to 96 per cent at Thunder Bay. There were no hours of very poor air quality recorded at AQI sties in Ontario during 2003.

Smog Advisory Days

In 2003, seven smog advisories were issued in Ontario, covering 19 days throughout the year. The first two advisories were multi-day events (i.e., June 22-26 and July 1-4), while the remaining advisories were two-day events (i.e., July 25-26, July 31-August 1, August 14-15, August 20-21, and October 10-11).

2.2 Trends in Air Quality

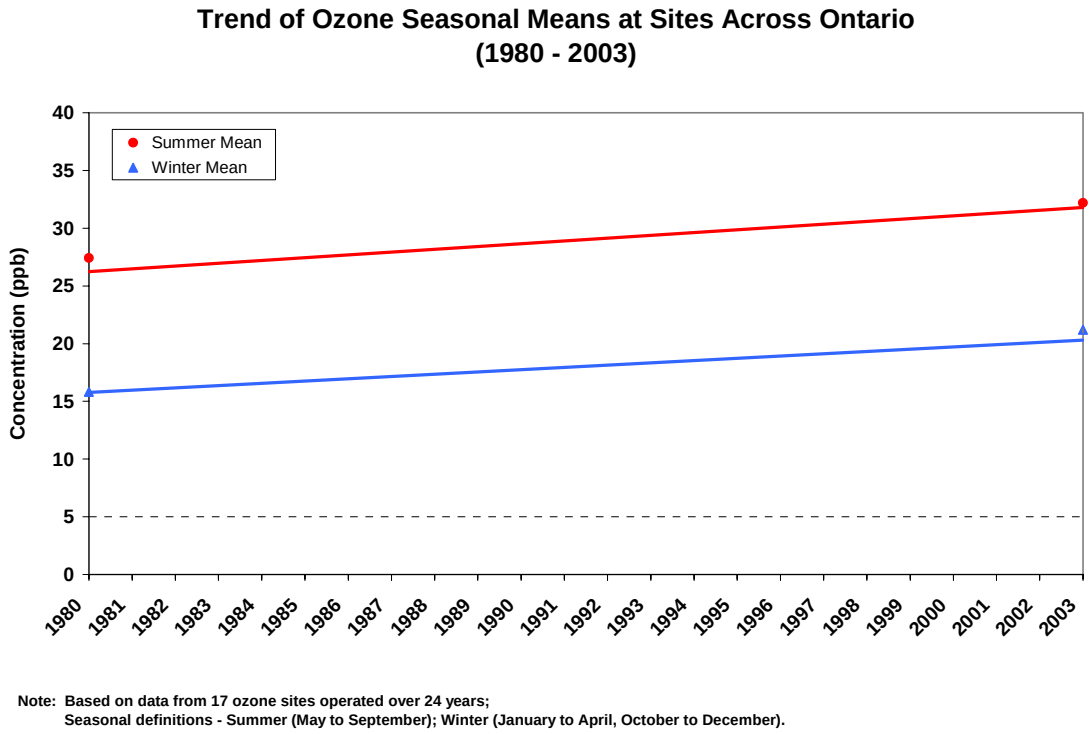
The data generated from the Ontario air quality monitoring stations has also been analyzed for both long-term average and short-term peak trends. In addition, these air quality monitoring data were used to support the AQI and Smog Alert programs. Ontario air quality monitoring data have been summarized in an annual summary report that has been published since 1971 (MOE, 2004a). Due to limited data, long-term trends have not been determined for all contaminants.

Ozone

Although some random fluctuations in ozone concentrations have been observed, the overall trend for one-hour maximum concentrations has been decreasing from 1980 to 2003. However, during this same time period, the seasonal ozone summer and winter means have been

increasing. The summer means have increased by approximately 21 percent and the winter means have increased by approximately 29 percent. The increase of the means has been attributed to the long-range transport of ozone and ozone precursors from the U.S. The trend in increasing seasonal means of ozone is shown in Figure 2.1.

Figure 2-1. Trend of Ozone Seasonal Means at Sites Across Ontario



Note: Based on data from 17 ozone sites operated over 24 years;
Seasonal definitions - Summer (May to September); Winter (January to April, October to December).

Source: Ontario Ministry of the Environment, 2004. Air Quality in Ontario 2003 Report, page 7.

MOE data also shows an increasing trend in the eight-hour average ozone levels for urban areas in southern Ontario from 1994 to 2003. Toronto and Hamilton experienced the highest percent increase of eight-hour ozone levels in the province, with a 19% and 20% increase respectively.

Fine Particulate Matter

Long-term trends for $PM_{2.5}$ have not been reported due to limited monitoring data. Although a total of 37 ambient air monitoring sites measured $PM_{2.5}$ in 2003, only one station existed in 1996. As a result, a 10-year time series cannot be generated.

Nitrogen Dioxide

The long-term trend for NO_2 has been downward, with provincial average ambient concentrations decreasing by 26 percent from 1975 to 2003.

Carbon Monoxide

The long-term trends for CO have been significantly decreasing in Ontario. Between 1990 and 2003, the composite average of the one- and eight-hour maximums have decreased by 63 and 55 percent, respectively. Likewise, the composite annual mean in 2003 was 26 percent less than the corresponding 1994 composite mean.

Sulphur Dioxide

The 2003 average ambient concentrations of SO_2 were approximately 86 per cent lower than concentrations reported in 1971. This significant decrease has been attributed to control orders on smelting operations and the Countdown Acid Rain program.

Total Reduced Sulphur Compounds

Based upon the provincial TRS annual mean concentrations from ambient monitoring data from 1990 to 2003, there is no discernible general trend.

VOCs

From 1994 to 2003, there is a significant downward trend of ambient concentrations of benzene, toluene, and xylene. These reductions are partially attributed to *The Benzene in Gasoline Regulations* and *Ontario's Gasoline Volatility Regulation*.

Smog Advisory Days

The number of smog advisory days is very dependent upon seasonal weather conditions. In 2001 and 2002, which were hotter and drier than 2003, there were 23 and 27 smog advisory days, respectively. However, in 2000, which had a cool and wet summer, there were only four smog advisory days.

2.3 Health Impacts of Individual Pollutants and Cited Health Impacts in Ontario

There are various recent reports and studies that cite the health and health-related economic impact of smog-related emissions in Ontario.

The Air Health Effects Division of Health Canada recently estimated the annual number of excess deaths attributable to current air pollution levels in Canada (Judek et al., 2004). These excess death estimates were provided for individual cities and were disaggregated into short-term and long-term exposures. On an annual basis for four cities in Ontario, an estimated 910 deaths were caused by short-term exposure, and 1,990 deaths were caused by long-term exposure. City-specific death estimates are presented in Table 2-1. These deaths account for approximately 8 per cent on average of total deaths in these cities.

Table 2-1. City-Specific Estimates of Death Due to Short- and Long-Term Exposures to Air Pollution

City	Short-Term Deaths	Long-Term Deaths
Toronto Division/Toronto Metropolitan Municipality	590	1,260
Hamilton Division/Hamilton-Wentworth Regional Municipality	130	330
Ottawa Division/Ottawa-Carleton Regional Municipality	110	230
Essex County/Windsor	80	170
Total	910	1,990

The Ontario Medical Association (OMA) released a report in June 2005 that estimated the number of smog-related premature deaths in the province. The OMA estimates that smog-related premature mortality accounts for approximately 5,800 deaths annually in the province. These deaths are attributable to emissions of O_3, $PM_{2.5}$, CO, SO_2 and NO_x. Approximately 4,000 of these deaths are a result of chronic exposure to these pollutants.

The OMA report estimates that the number of smog-related premature deaths will increase, with the elderly most at risk, and children and infants with compromised health conditions also at risk. The OMA also estimates that the number of hospital admissions and emergency room visits, and costs to the health care system and the economy as a result of smog-related illnesses will increase by 2015. Table 2-2 shows the estimates from the OMA for 2005, 2010 and 2015.

City of Toronto Public Health (TPH) recently published two reports that estimate air pollution contributions to premature deaths in the City of Toronto. In its 2004 report entitled Air Pollution Burden of Illness Study, Toronto Public Health considered both the chronic and acute effects of air pollution in Toronto. In this report, TPH estimates that air pollution contributes to 1,700 premature deaths, and 6,000 hospital admissions in Toronto per year. Of these deaths, 695 are attributable to acute (short-term) exposures while the rest are associated with chronic (long-term) exposure to PM2.5.

Table 2-2. OMA Smog-Related Health Impacts 2005, 2010 and 2015

	2005	2010	2015
Premature deaths	5,829 deaths	Approx. 6,500 deaths	7,436 deaths
Hospital Admissions**	16,807 admissions	Approx. 18,000 admissions	20,067 admissions
Emergency Room Visits	59,696 visits	Approx. 65,000 visits	71,548 visits
Economic costs Health care costs Total costs	 $507 million $7.8 billion	 N/A	 $571 million $9.8 billion

** Most hospital admission cases are associated with cardiovascular illnesses attributable to O_3 and $PM_{2.5}$

In a June 2005 by TPH entitled Influence of weather and air pollution on mortality in Toronto. Summary Report of Differential and Combined Impacts of Winter and Summer Weather and Air Pollution due to Global Warming on Human Mortality in South-Central Canada, TPH estimated 822 premature deaths in the City per year related to acute exposure to five common smog pollutants. The report projects that the number of premature deaths related to air pollution will increase 20% by 2050.

Additional reports have estimated the number of premature deaths, costs to the economy and the health care system, and other health impacts associated with smog in Ontario. These reports are cited here:

- Ontario Ministry of the Environment, June 2005, Transboundary Air Pollution in Ontario.
- DSS Management Consultants Inc. and RWDI Air Inc., April 2005. Report prepared for the Ontario Ministry of Energy, Costs Benefit Analysis – Replacing Ontario's Coal-Fired Electricity Generation.

Ozone

Ground-level ozone is a colorless, odorless gas that irritates both the respiratory tract and the eyes. Exposure to ozone can result in coughing, wheezing, and chest tightness among sensitive populations. Sensitive populations include children, elderly people, and individuals with pre-existing respiratory disorders (e.g., asthma and other chronic lung diseases). Ground-level ozone triggers asthma attacks, but can also cause asthma, damage the lungs and thereby reduce lung function.

It has been estimated that the annual acute air pollution-related burden of illness for Toronto due to ozone is 219 acute premature deaths and 337 respiratory hospital admissions. However, it is not currently known if a chronic long-term risk is associated with ozone (TPH, 2004).

Fine Particulate Matter

Fine particulate matter ($PM_{2.5}$) is formed either directly through fuel combustion or indirectly through a series of complex chemical reactions in the atmosphere. Fine particulate matter, a pollutant of concern, can penetrate deep into the lungs. Adverse health effects have been identified for both short- and long-term timeframes. The most sensitive populations are people with asthma or cardiovascular or lung disease, children, and elderly people. Studies have found that long-term exposure to fine particulates can lead to increased risk of lung cancer and cardiopulmonary disease. Exposure to fine particulate matter is a risk factor for acute health impacts including stroke deaths.

The annual acute air pollution-related burden of illness for Toronto due to fine particulate matter is estimated to be 177 acute premature deaths and 1,018 hospital admissions (597 respiratory-related admissions and 421 cardiovascular-related admissions). In addition to these acute effects, the annual chronic air pollution-related burden of illness (i.e. premature mortality) for Toronto for fine particulate matter has been estimated to be 1,236 (TPH, 2004).

Diesel fuel combustion is a significant source of $PM_{2.5}$ and there are various studies linking health impacts with exposure to diesel exhaust pollutants. Studies have reported a causal link between diesel and asthma, with evidence that diesel exhaust particles can irritate human airways causing inflammation and triggering attacks. Other studies in the United States have linked long-term exposure to PM that is emitted by diesel fuel combustion to lung cancer and cardiopulmonary mortality. The U.S. Environmental Protection Agency (EPA) has concluded that diesel exhaust ranks with among other toxics in posing the greatest carcinogenic risk in the U.S. nationwide. Studies have also raised concerns about the exposure of children to high diesel exhaust levels in school buses.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a reddish-brown gas with a very pungent and irritating odor. Nitrogen oxides contribute to the formation of nitrates, which increase fine particulate levels in the atmosphere and contribute to the formation of ozone. Exposure to NO_2 can irritate the lungs, which may result in an overall lowered resistance to respiratory infection. Sensitive populations include people with asthma and bronchitis.

The annual acute air pollution-related burden of illness for Toronto due to NO_2 is estimated to be 249 acute premature deaths and 4,318 hospital admissions (1,461 respiratory-

related admissions and 2,857 cardiovascular-related admissions). However, it is not currently known if a chronic long-term risk is associated with NO_2 (TPH, 2004).

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas. It is primarily produced through the incomplete combustion of fossil fuels. Carbon monoxide can enter the bloodstream and reduce the delivery of oxygen to the organs and tissues. People with heart disease are particularly sensitive. Exposure to high CO levels is linked to impairment of vision, work capacity, learning ability and performance of complex tasks.

It has been estimated that the annual acute air pollution-related burden of illness for Toronto due to CO is 20 acute premature deaths and 272 respiratory-related hospital admissions. However, it is not currently know if a chronic long-term risk is associated with CO (TPH, 2004).

Sulphur Dioxide

Sulphur dioxide (SO_2) is a colorless gas that is produced primarily by industrial facilities. Sulphur dioxide also contributes to the formation of sulphates, which increase fine particle levels in the atmosphere. Health effects caused by exposure to high SO_2 levels include breathing problems, respiratory illness, and worsening respiratory and cardiovascular disease. Sensitive populations include people with asthma, chronic lung disease, or heart disease.

The annual acute air pollution-related burden of illness for Toronto due to SO_2 has been estimated to be 30 acute premature deaths and 319 hospital admissions (215 respiratory-related and 104 cardiovascular-related admissions). However, it is not currently known if a chronic long-term risk is associated with SO_2 (TPH, 2004).

Total Reduced Sulphur Compounds

Total reduced sulphur (TRS) compounds produce a distinctive smell similar to rotten eggs or cabbage. Although TRS compounds can be a source of nuisance odors, they are generally not considered to be an acute short-term health hazard. In terms of long-term health impacts, TRS compounds are not generally considered to be a hazard, however several agencies in the U.S. (e.g. U.S. EPA) have established stringent guidelines for hydrogen sulphide, a primary TRS compound, to protect against chronic health effects.

VOCs

VOCs typically have significant human health effects. For instance, benzene is a known human carcinogen. Although toluene and xylene are not carcinogens, both have been identified as central nervous system depressants. Specific acute or chronic health effects have not been specifically quantified for the Toronto area.

2.4 Emissions from Vehicles – Current and Projected

Motor vehicle emissions constitute a significant portion of the current 2005 emissions inventory for Ontario. Table 2-3 presents total on-road motor vehicle and nonroad mobile source baseline (no I/M program) inventory emissions. On-road motor vehicle sources include light-duty vehicles (gasoline and diesel), light-duty trucks (gasoline and diesel), heavy-duty vehicles/trucks (gasoline and diesel), motorcycles, and tire wear and brake lining. Nonroad mobile sources include off-road use of gasoline and diesel, air transportation, marine transportation, and rail transportation. In addition to the results from the current 2005 inventory, Tables 2-4 and 2-5 present projected baseline (no I/M program) inventories for 2010 and 2015.

Table 2-3. 2005 Criteria Air Contaminants Emissions for Ontario (Tonnes/yr)

	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
On-road	156,327	735	77,678	1,415,077	3,923	2,572
Nonroad	182,681	23,432	84,153	1,007,766	16,073	14,613
Total Transportation	339,008	24,167	161,831	2,422,843	19,996	17,815

Table 2-4. 2010 Criteria Air Contaminants Emissions for Ontario (Tonnes/yr)

	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
On-road	95,652	683	53,419	1,233,525	3,181	1,826
Nonroad	171,399	25,213	74,960	1,098,498	14,401	13,052
Total Transportation	267,052	25,896	128,377	2,332,024	17,583	14,879

Table 2-5. 2015 Criteria Air Contaminants Emissions for Ontario (Tonnes/yr)

	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
On-road	50,936	739	37,705	1,126,944	2,841	1,431
Nonroad	165,103	26,492	74,426	1,191,137	14,411	13,490
Total Transportation	216,041	27,232	112,130	2,318,082	17,251	14,921

In the 2005 inventory, the comparative contributions of the on-road and nonroad components vary depending upon the pollutant. For NO_x, VOC, and CO, the on-road sources comprise a significant portion of emissions from the transportation sector. The emissions from on-road sources in tonnages and as a percentage of the emissions from the transportation sector

are projected to decrease for pollutants such as NO_x, VOC, PM_{10} and $PM_{2.5}$ from 2005 to 2015, while CO emissions from on-road sources are projected to remain stable during that period.

The emissions contributions of the eight on-road motor vehicle source categories in Ontario for the 2005 inventory year are presented in Table 2-6. The contribution of these source categories relative to the total on-road motor vehicle inventory is presented in Table 2-7.

Table 2-6. 2005 On-Road Motor Vehicle Source Category Criteria Air Contaminants Emissions for Ontario (Tonnes/yr)

	NO_x	**SO_x**	**VOC**	**CO**	**PM_{10}**	**$PM_{2.5}$**
LDGV	51,682	420	56,885	1,095,846	280	260
LDGT	15,328	108	15,833	287,703	88	72
HDGV	3,108	13	660	9,644	43	38
LDDV	379	3	129	593	47	43
LDDT	516	6	199	395	42	38
HDDV	84,979	185	3,056	17,296	1,633	1,503
Motorcycles	337	1	916	3,600	5	3
Tire/Brake	0	0	0	0	1,785	615
Total On-road emissions	156,327	735	77,678	1,415,077	3,923	2,572

Table 2-7. 2005 On-Road Motor Vehicle Source Category Criteria Air Contaminants Emissions for Ontario (% of Total On-Road Motor Vehicles)

	NO_x	SO_x	VOC	CO	PM_{10}	$PM_{2.5}$
LDGV	33.1%	57.1%	73.2%	77.4%	7.1%	10.1%
LDGT	9.8%	14.7%	20.4%	20.3%	2.2%	2.8%
HDGV	2.0%	1.8%	0.8%	0.7%	1.1%	1.5%
LDDV	0.2%	0.4%	0.2%	0.0%	1.2%	1.7%
LDDT	0.3%	0.8%	0.3%	0.0%	1.1%	1.5%
HDDV	54.4%	25.1%	3.9%	1.2%	41.6%	58.4%
Motorcycles	0.2%	0.1%	1.2%	0.3%	0.1%	0.1%
Tire/Brake	0.0%	0.0%	0.0%	0.0%	45.5%	23.9%
Total On-road emissions	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

As shown in these tables, light-duty gas vehicles and light-duty gas trucks are the primary on-road motor vehicle contributors of VOC, CO, and SO_x. For NO_x, heavy-duty diesel vehicles are the largest sources, while for PM_{10} and $PM_{2.5}$, the greatest emissions are from heavy-duty diesel vehicles and brake/tire wear.

2.5 Federal Government Initiatives to Reduce Mobile Emissions

Several significant federal and provincial initiatives (i.e. programs, regulations, etc.) related to cleaner motor vehicles and fuels will lead to reduced motor vehicle emissions in future years (MOE, 2004b). Federal initiatives are briefly outlined below:

- Gasoline Sulphur Regulations: Gasoline sulphur levels have been reduced throughout Canada. From July 2002 to December 2004, the required average sulphur level was 0.015% (150 ppm). Beginning in 2005, the required sulphur level was reduced to 0.003% (30 ppm).
- Diesel Sulphur Regulations: Beginning in mid-2006, the average sulphur level for diesel will be limited to a maximum of 15 mg/kg (15 ppm).
- On-road Vehicle and Engine Emissions Regulations (analogous to U.S. EPA's New Vehicle Emissions Certification Standards): More stringent manufacturers' emission standards applicable to light-duty vehicles, new light-duty trucks, heavy-duty vehicles, heavy-duty engines, and motorcycles are expected to result in significant emission reductions. Between 2004 and 2009, the new light-duty vehicle standards are expected to produce significant emission reductions (e.g., 91 percent for fine particulate matter, 90 percent for NO_x, and 71 to 84 percent for VOCs). Likewise, between 2007 and 2010, the new heavy-duty vehicle standards are also expected to produce large emission reductions (e.g., 90 percent for fine particulate matter and 95 percent for NO_x).

2.6 Ontario Government Initiatives to Reduce Mobile Emissions

In addition to the federal government initiatives described in Section 2.5, several additional Ontario government initiatives have been implemented in order to reduce mobile source emissions (MOE, 2004b). These initiatives are briefly outlined below:

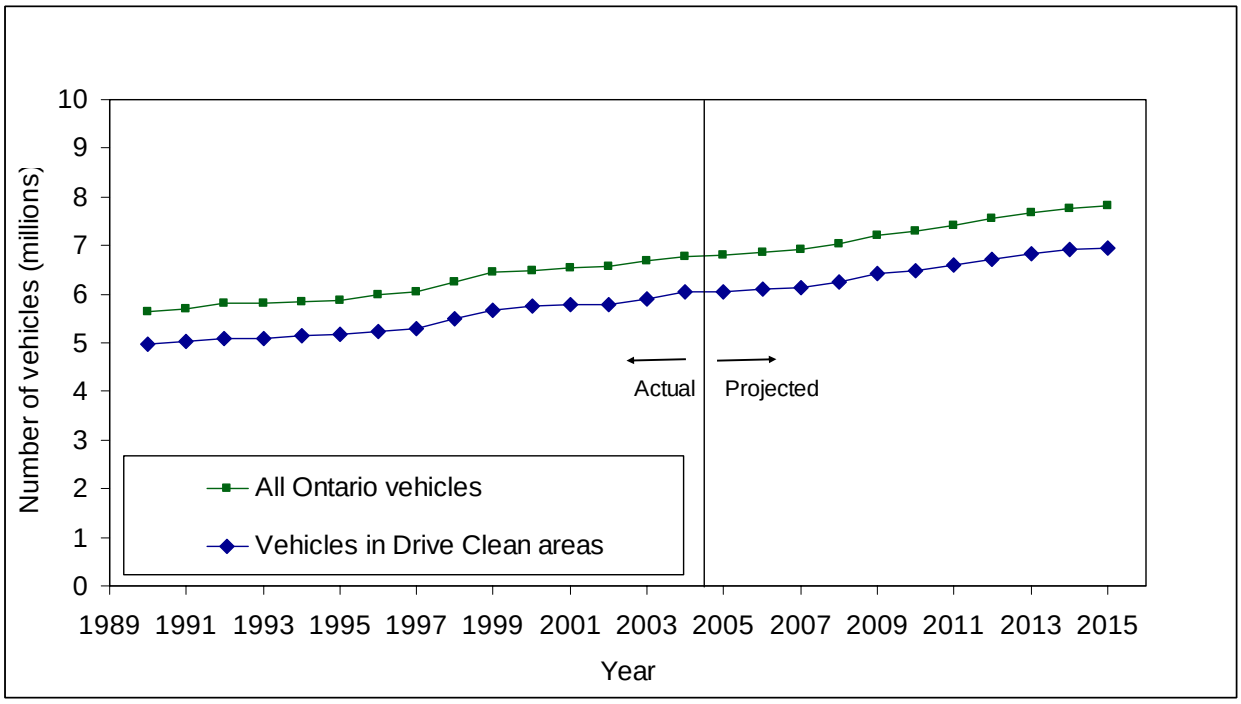
- *Drive Clean* Program; Ontario's mandatory vehicle emissions inspection and maintenance program has reduced smog-causing VOC and NOx emissions from light duty vehicles (LDV) in the southern Ontario smog zone by more than 81,200 tonnes since it began in 1999 through to 2003. Between 2000 and 2002, the program is estimated to have reduced Particulate Matter (PM) from diesel heavy-duty vehicles (HDV) by nearly by nearly 1,100 tonnes.
- Smog Patrol: Ontario's Smog Patrol has conducted over 37,000 inspections of vehicles with excessive exhaust smoke or tampered emissions control equipment and issued more than 6,000 tickets since 1998.
- Government fleet fuels: The government of Ontario has also taken the lead in controlling emissions by adopting various types of fuels that reduce emissions. Some examples include the use of ethanol-blended gasoline in the government vehicle fleet and the year-round use of low-sulphur diesel in the transit bus fleet. In addition, a sales tax rebate program has been implemented for vehicles powered by alternative fuels.
- Fuel taxes: Ontario has a number of fuel tax exemptions that encourage the use of emission-reducing fuels. These include a fuel tax exemption of 14.3 cents/liter for bio-diesel fuel (either mixed or unmixed with diesel), a gasoline tax exemption of 14.7 cents/liter for ethanol and the ethanol portion of ethanol-blended gasoline, and a fuel tax exemption for natural gas used to power licensed motor vehicles.

3.0 Overview of the Vehicle Fleet in Ontario (Present and Future)

3.1 LDV – Vehicle Fleet – Current and Future Trends to 2015

DesRosiers Automotive Consultants (2005) provided historical trends and future projections of the light-duty vehicle fleet in Ontario and the *Drive Clean* areas of the province. Figure 3-1 shows the trends in the number of vehicles registered in Ontario over time. Historically, vehicles registered inside of the *Drive Clean* program areas accounted for about 88% of all vehicles registered in Ontario and this portion is expected to vary little by 2015. DesRosiers forecasts that LDV fleet will grow at a rate of 1.9% per year on average to 2015, from the 1990 vehicle population estimate.

Figure 3-1. Number of Registered Light-Duty Vehicles in Ontario, by Year



The Ministry of Transportation provided a file of all vehicles registered in Ontario as of January 2005 (the file included vehicles whose registration had lapsed up to 6 months; in other words, vehicles whose registration had expired between July and December 2004). We assigned each vehicle to the *Drive Clean* phase areas by the postal code at which it was registered. Table 3-1 shows the number of light-duty vehicles registered in Ontario as of 2004, by phase and general fuel type. Approximately 98% of all light-duty vehicles are gasoline-powered, while only 1.8% are diesel-powered. A very small number of light-duty vehicles use alternative fuels such as propane, natural gas, hybrid-electric, or full electric.

Table 3-1. Number of Light-Duty Vehicles Registered in Ontario in 2004, by Phase and Fuel Type

Fuel type	Area				Total	Distribution
	Non-I/M	Phase 1	Phase 2	Phase 3		
Diesel	22,496	44,012	37,820	23,752	128,080	1.8%
Gasoline	794,636	3,099,700	1,849,320	1,130,398	6,874,054	97.9%
Other	1,722	7,150	4,808	2,737	16,417	0.3%
Total	**818,854**	**3,150,862**	**1,891,948**	**1,156,887**	**7,018,551**	**100.0%**
Diesels	18%	34%	30%	19%	100%	
Gasoline	12%	45%	27%	16%	100%	

Figures 3-2 shows the number of light-duty gasoline vehicles registered in Ontario in 2004, by phase and model year. The vertical lines in the figure show the model years that were subject to *Drive Clean* testing in 2004 (model years 1985 to 2001).

Figure 3-2. Number of Registered Light-Duty Gasoline and Diesel Vehicles in 2004, by Phase and Model Year

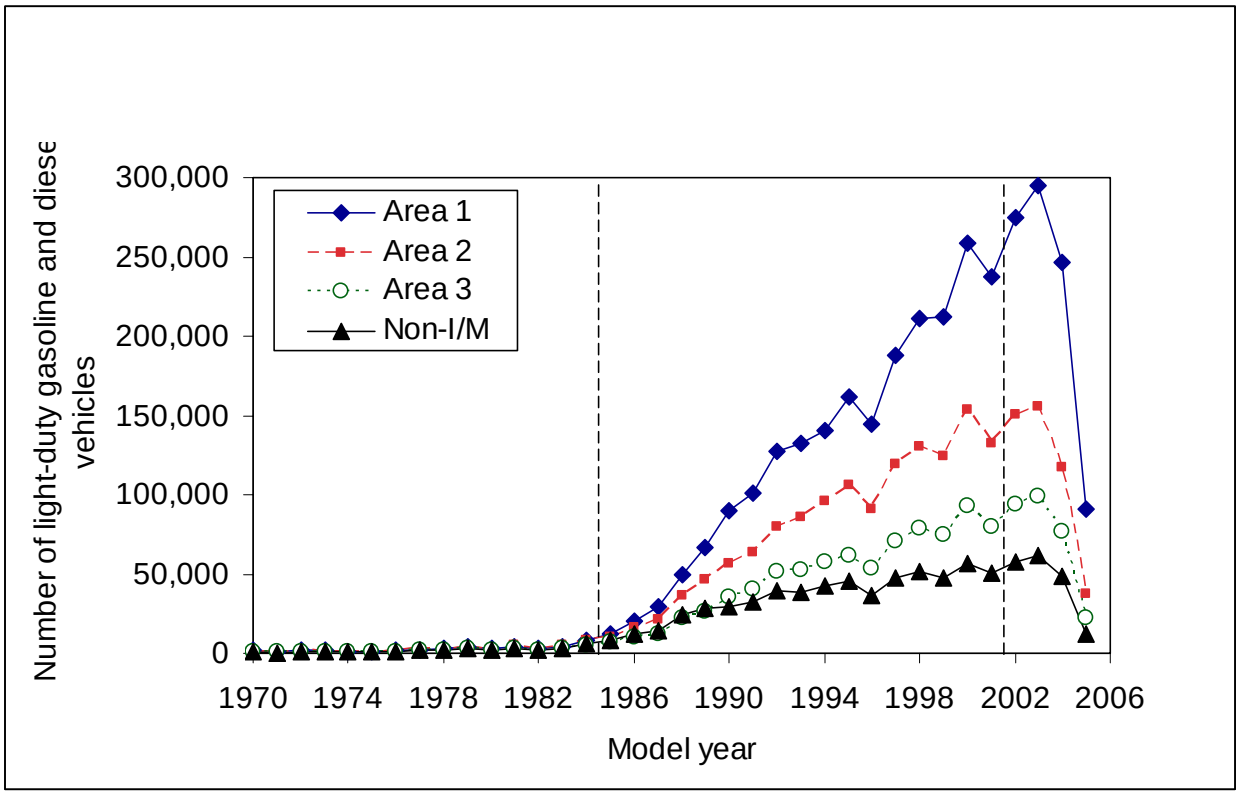
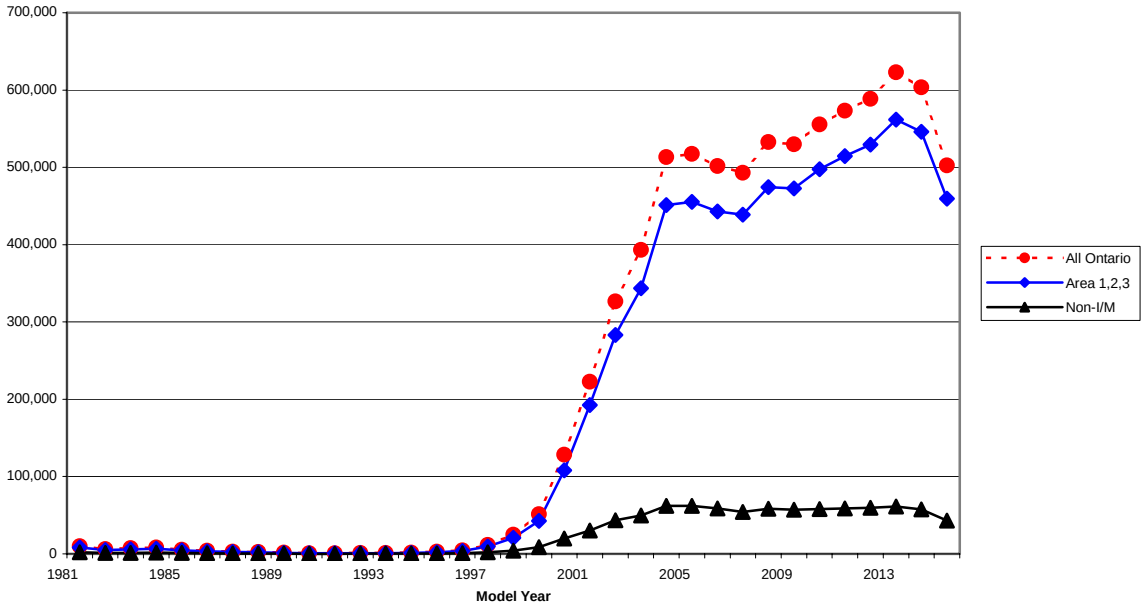


Figure 3-3 shows the projected number of light-duty vehicles that will be registered in Ontario in 2015, by model year. These projected numbers are presented for total vehicles, I/M areas (i.e., Phase 1, 2, and 3), and non-I/M areas (DesRosiers, 2005).

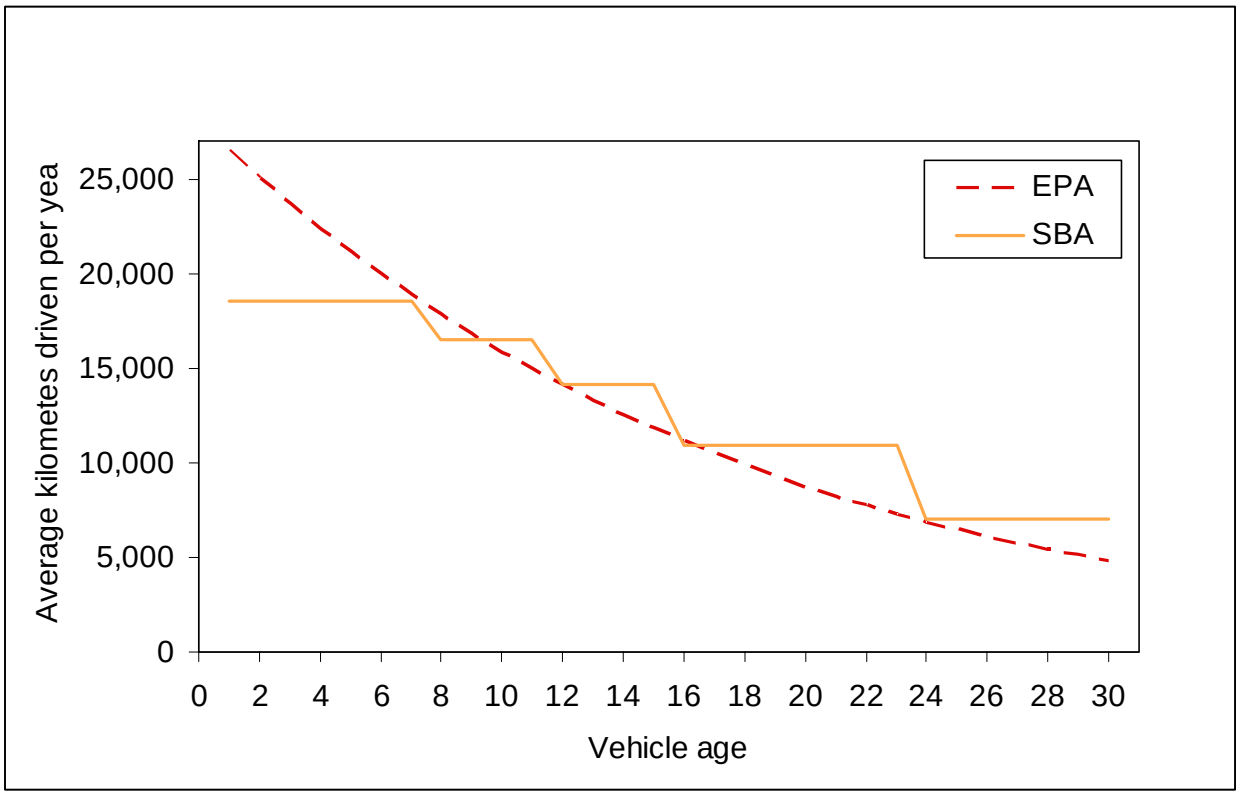
Figure 3-3. Projected Number of Registered Light-Duty Vehicles in 2015, by Phase and Model Year



The overall composition within the light-duty vehicle fleet is expected to change somewhat due to increased used vehicle sales relative to new vehicle sales, as well as consumer preferences that favour light-duty trucks over passenger cars. The current trend of increasing market share for SUVs and light trucks may continue or change depending on a variety of factors, including fuel costs, the economy, and consumer preferences. Technology costs such as the competitive positioning of hybrid vehicles will influence the penetration of larger vehicles with car-like emissions. In 2004, the average light-duty vehicle age is 6.4 years, and is expected to increase gradually to 7.2 years by 2015. However, average age does not describe the age distribution, which is heavily skewed towards newer vehicles and trails off gradually to vehicles that are 20 years old or more (1-3% of the total vehicle population).

Figure 3-4 shows estimated annual light-duty vehicle use by vehicle age, from two sources: estimates for model-year groups used by Stewart-Brown Associates (SBA) for their estimates of the emission reductions from the *Drive Clean* program (based on actual odometer readings for millions of vehicles in the *Drive Clean* program), and estimates by U.S. EPA used in the MOBILE6.2 emissions model. Both estimates show that annual vehicle kilometers driven decrease dramatically as vehicles age. For the most part the SBA estimates match those in the U.S. EPA MOBILE model.

Figure 3-4. Average Kilometers Driven per Year by Light-Duty Vehicles, by Source and Vehicle Age



Percent of Vehicles with New Technologies

New emissions control technologies continue to be introduced into the vehicle fleet, continually lowering baseline emission rates. However, the introduction of new technologies and standards will take a few years to penetrate the Ontario vehicle fleet. Penetration of some new technologies, such as hybrid vehicles, fill a niche and are market driven so that they may be replaced with other niche products before they become a major segment of the in-use vehicle population. Other new emissions control technologies that are installed in all vehicles starting with a particular model year, such as on board diagnostic (OBDII) systems, can represent more than 50% of in-use Ontario vehicles within 5-6 years. The U.S. EPA's MOBILE6.2C emission factor model automatically accounts for the introduction of new emission standards and technologies, including OBDII, the recent Tier 2 light-duty standards, and the 2004 heavy diesel standards.

On-board diagnostic (OBDII) systems were installed in all LDVs sold in Ontario starting in 1998. ODBII systems monitor the functioning of the emissions control components installed on vehicles and can provide diagnostic read-outs of any problems. Vehicle population data in

the DesRosiers report indicated that in 2004, 55.8% of LDVs were equipped with OBDII systems, but only 38.0% of vehicles requiring an emissions test for registration renewal in 2004 were OBDII equipped. These percentages are increasing rapidly, and by 2007, 77.0% of all LDVs will be equipped with OBDII, and 78.4% of vehicles requiring an emissions test for registration renewal in 2007 will be equipped with OBDII systems. By definition, if vehicles require an emissions test for registration for registration renewal up to and including 19 year old vehicles, when 1998 vehicles are 19 years old (2017), 100% of the vehicles in the program will be equipped with OBDII. However, the entire Ontario on-road fleet would not be expected be equipped with OBDII even after 30 years, since a small number of pre-1998 vehicles will continue to be registered and driven.

DesRosiers estimates that hybrid vehicles currently account for about 0.3% of total light-duty vehicle sales and sales are expected to reach about 1% by 2015, or 4,000 to 4,800 vehicles per year by 2015.

As manufacturers do not release sales figures by model, it is difficult to estimate how many hybrids are in the in-use fleet. Vehicle manufacturers will follow the U.S. emissions standards for new vehicles which has led to the manufacture of vehicles meeting Tier 1 standards (sold from 1992 to 2005) and vehicles meeting Tier 2 standards (sold from 2005 on).

Fuels

US EPA's MOBILE model includes factors that account for the impact on emissions of improvements in gasoline formulation, for example gasoline volatility (Reid Vapour Pressure - Gasoline Volatility Regulation O.Reg. 271/91), sulphur content (from Environment Canada publication reporting sulphur levels by the refineries), and gasoline composition (concentration of aromatics, benzene, olefins, and ethanol) based on an Environment Canada study.

No additional adjustment is necessary for fuels to estimate the vehicle emissions baseline inventories using the MOBILE model. In general, now that sulphur has been lowered to California levels, there are no obvious improvements for fuels in Ontario on the horizon that would have a positive impact on emissions.

3.2 HDV Vehicle Fleet – Current and Future Trends to 2015

Table 3-2 shows the number of heavy-duty vehicles registered in Ontario as of 2004, by fuel type. 84% of all heavy-duty vehicles are diesel-powered, while 15% are gasoline-powered. A very small number of heavy-duty vehicles use alternative fuels such as propane and natural

gas. The bottom of Table 3-2 indicates that 18% of the heavy-duty gasoline vehicles in Ontario are registered in the non-I/M portion of the province.

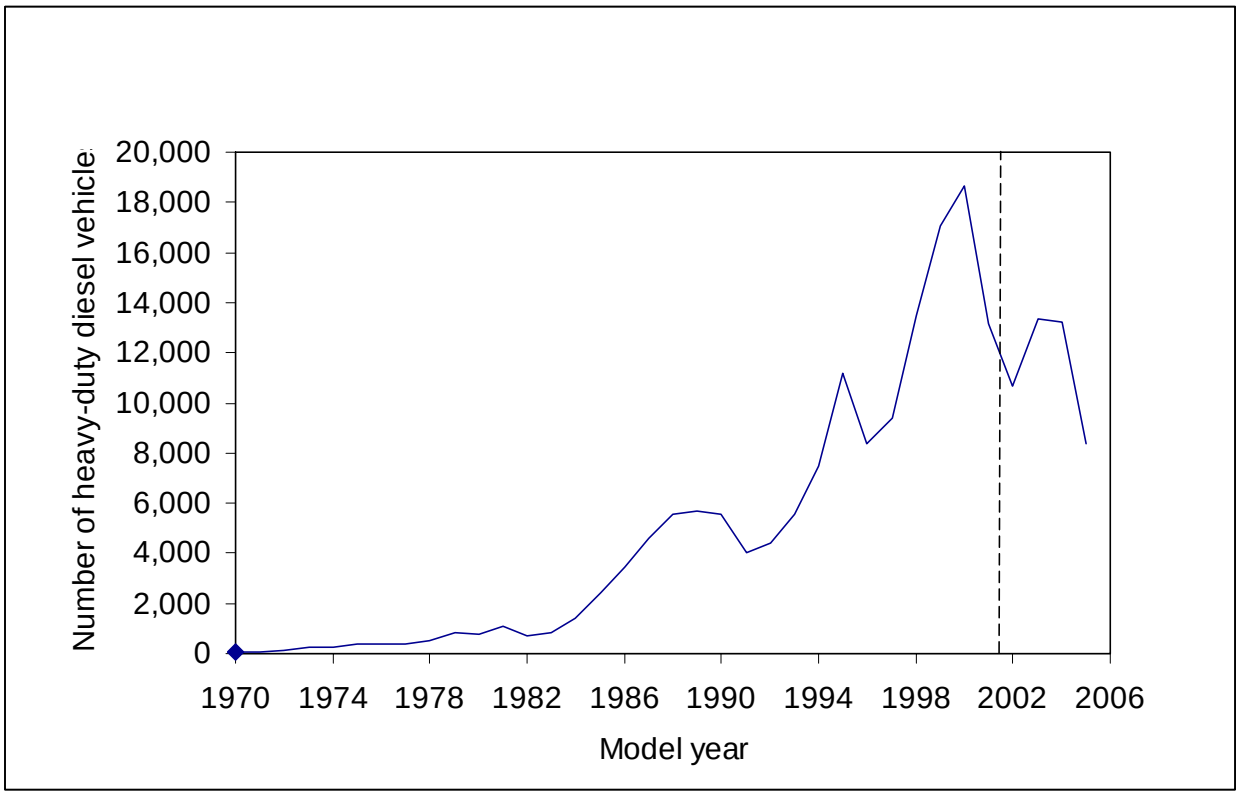
Table 3-2. Number of Heavy-Duty Vehicles Registered in Ontario in 2004, by Phase and Fuel Type

	Area					
Fuel type	**Non-I/M***	**Phase 1**	**Phase 2**	**Phase 3**	**Total**	**Distribution**
Diesel (*ALL in program)					191,064	84.2%
Gasoline	5,971	13,319	9,226	5,505	34,021	15.0%
Other non-diesel	210	1,026	477	172	1885	0.8
Total	31,272	97,587	64,380	33,731	226,970	100.0%
Diesel (*All in program)					100%	
Gasoline	18%	39%	27%	16%	100%	

Estimating the number of heavy-duty vehicles registered in Ontario is difficult as the Registered Gross Weight in the Ministry of Transportation database is assigned by the vehicle owner based on the expected on-road weight of the vehicle. Vehicles towing heavy trailers are required to register the vehicle with the combined vehicle plus trailer weight even though the vehicle may be light-duty. The MTO file also includes the gross vehicle weight rating (GVWR) for all vehicles, which is the manufacturer specification for the maximum gross loaded weight for vehicles. The GVWR in the MTO file is unreliable, as it is not verified, comes from several sources, and may be in kilograms or pounds. Consequently, it is very difficult to estimate the actual fleet size of both diesel and non-diesel heavy-duty vehicles. However, recognizing the GVWR is often incorrect in registration databases, we categorized the vehicles into light-and heavy-duty based on their body style. We included all “cab and chassis” vehicles in the heavy-duty category; 21,000 cab and chassis diesel trucks, and 12,000 cab and chassis gasoline trucks, have a reported GVWR of less than 10,000 lbs. Therefore, we may be understating the number of light-duty vehicles, and overstating the number of heavy-duty vehicles, by about 21,000 diesel and 12,000 gas trucks in Tables 3-1 and 3-2.

Figure 3-5 shows the number of heavy-duty gasoline and diesel vehicles registered in Ontario, by phase and model year. It should be noted that there are a relatively large number of older heavy-duty gasoline vehicles in Ontario, compared to heavy-duty diesel and light-duty vehicles.

Figure 3-5. Number of Heavy-Duty Diesel and Gasoline Vehicles Registered in *Drive Clean* Areas in 2004, by Model Year



Based on projected vehicle populations, the future heavy-duty fleet will figure more significantly in the overall vehicle fleet. The vehicle populations used by Ontario in their 1985-2020 motor vehicle emission estimates point to a slightly larger percent of heavy-duty vehicles[2]. For instance, the overall vehicle fleet in 2004 consisted of 95.2% light-duty gasoline vehicles, 1.3% light-duty diesel vehicles, 0.8% heavy-duty gasoline vehicles, and 2.7% heavy-duty diesel vehicles. The overall vehicle fleet in 2015 is projected to consist of 93.6% light-duty gasoline vehicles, 1.8% light-duty diesel vehicles, 1.3% heavy-duty non-diesel vehicles, and 3.3% heavy-duty diesel vehicles. The fraction of heavy-duty vehicles in the overall fleet is projected to increase from 3.5% to 4.6% from 2004 to 2015, but the increase is within a +3% level of uncertainty for LDVs. Because of the potential large NO_x and $PM_{2.5}$ emissions from heavy-duty vehicles, this future increase of heavy-duty vehicles should be considered in future I/M program design. At the same time, the US has mandated the installation of major emissions reductions

[2] Updated Criteria Air Contaminants Emissions of Ontario On-Road Mobile Source for Years 1985-2020, CW Environmental Consulting, Inc., November 2004.

technologies in diesel heavy-duty vehicles starting in 2008 so that these future vehicles will meet drastically reduced emissions standards for particulates and NO_x.

4.0 Costs and Benefits of *Drive Clean* Program

4.1 Introduction

ERG estimated emission reductions and costs for both historical and future year scenarios, for the current light-duty I/M program as well as several program options. Historical benefits and costs of the current program were obtained from previous analyses conducted for the DCO. Emission reductions for the historical analyses were based on modeling and actual before and after-repair test measurements, and applied to the fleet as a whole. Since estimates of future year program benefits cannot be based on actual measurements, emissions models were used for these scenarios. ERG used the MOBILE6.2C emission factor model to estimate emission reductions for the current light-duty program in 2005, 2010, and 2015. In addition, MOBILE6.2C modeling was also conducted to determine the impact selected options would have on emissions.

Note that quantification of emission reductions for some program options was not possible using MOBILE6.2C (for example, cutpoint modifications, early retirement programs, and other options).

Once established, emission benefits were combined with cost data for the current I/M program, as well as selected program options, to estimate cost-effectiveness in dollars per tonne of emission reduction. Cost estimates were taken from a variety of sources, as described below. Certain real, but hard-to-quantify costs such as driver inconvenience are not included explicitly in the final dollar per tonne values.

The actual denominator of the cost-effectiveness ratio is intended to reflect the relative contribution of each pollutant toward ozone formation in the Drive Clean area. The precise weighting factors can vary from region to region, depending upon meteorological and other site-specific conditions. The California and British Columbia I/M programs have used two different weighting rations in their cost-effectiveness calculations in the past; tonnes of HC+NOx, and HC+NOx+CO/7.[3,4,5] To facilitate comparison and reference with these other programs cost-effectiveness is expressed in terms of both factors for the base case program, and in terms of HC+NOx+CO/7 for each alternative analysis. The CO weighting factor of 1/7 was confirmed to

[3] Levelton 2004.
[4] California Air Resources Board, 1997 GSEMODEL Operating Instruction, Appendix A.
[5] California Air Resources Board, Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program, submitted to the IMRC, April 2004

be generally applicable to "typical" urban corridors.[6] Nevertheless, ERG recommends further evaluation to determine the most appropriate pollutant weighting factors specifically for the Ontario area.

Finally, there are great uncertainties associated with estimating both costs and future year particulate matter reductions for heavy-duty vehicle test and repair. In contrast to LDV, there is no generally accepted emissions model available to project future HDV emissions reductions from I/M programs. There is also no established cost-effectiveness benchmark for HDV I/M programs, and little information available to compare against the few HDV I/M programs in North America.

Therefore only historical emission reduction estimates are presented for the current heavy-duty test program, rather than a full cost-effectiveness estimate.

4.2 Emissions Reductions – Historical Analysis

As noted above, detailed emission reduction estimates were previously developed for the light-duty program using before and after repair emission test measurements.[7] The methodology used to generate these estimates is substantially different than that used in the MOBILE models, with its own strengths and weaknesses. The main advantage of this approach is its reliance on real-world data on actual vehicles. Finally, the SBA estimates are based on before and after-repair emissions of a relatively small sample of vehicles given a mass emission test in British Columbia. This sample does not include many 1991 and newer vehicles.

The historical benefit analyses performed for *Drive Clean* (see Table 4.1) provide an independent point of reference to the MOBILE modeling results discussed below.

[6] Factor derived from standard Maximum Incremental Reactivity (MIR) values developed by California ARB -- Personal communication with Dr. Jim Smith, photochemical modeler with the Texas Commission on Environmental Quality, July 8, 2005.

[7] *Drive Clean* Program Emissions Benefit Analysis and Reporting – Light Duty Vehicles and Non-Diesel Heavy-Duty Vehicles – 1999 to 2003 (prepared by Stewart Brown Associates), PIBS 5015e, Queen's Printer for Ontario, 2005.

Table 4-1. Historical Program Benefit Evaluation (Tonnes/Yr)

Year	HC	CO	NOx	HC+NOx	HC+NOx+CO/7
1999	3,331	45,325	1,741	5,072	11,547
2000	7,547	90,939	3,434	10,981	23,972
2001	11,282	120,817	4,617	15,899	33,159
2002	17,783	239,525	8,437	26,220	60,438
2003	17,529	199,989	5,591	23,120	51,690
Total	**57,472**	**696,595**	**23,820**	**81,292**	**180,806**

Source: SBA 2005, Table 6D

4.3 MOBILE6.2C Modeling – Future Year Projections and Options Evaluation

In order to assess I/M benefits in future years, as well as the effects of selected program options, ERG conducted MOBILE6.2C emissions modeling for a number of different scenarios. For each scenario, three calendar years (2005, 2010, and 2015) were analyzed, and separate model inputs were processed for each season and program phase of interest. In each run, HC, CO, NO_X, CO_2, PM_{10} and $PM_{2.5}$ emissions were calculated, in addition to toxic compounds, including benzene, 1,3 butadiene, formaldehyde, acetaldehyde, and acrolein.

Table 4-2 presents the scenarios that were modeled in this analysis. Detailed explanations of the modeling procedure are provided later in this section. These options are described in more detail in Section 6.

Table 4-2. Modeled I/M Scenarios

Scenario	Description
Base Case (no I/M)	Original case for comparison; no I/M modeled
Base Case (with I/M)	Modeled ASM 2525 for Light-Duty Vehicles, Two-Speed Idle for Heavy Gas Vehicles
Model year exemption set at 5 years	Model year exemption of 5 years, as opposed to 3 years used in other runs
OBDII - 98 and newer	Modeled OBDII for 1998+ model years
Heavy duty reflash	Modeled Factor of 0.3 for Adjusted Rebuild Effects (all other runs 0.07)
One cycle conditional pass	Drop repeat waiver rate from 1.6 to 0
I/M Program covering 1981+ vehicles	Increase program coverage to include all vehicles from model year 1981 onward
OBD/ASM Overlap	Accounted for vehicles that fail both OBD and ASM, netting out their mutual contribution

Just as with the SBA methodology discussed above, use of the MOBILE model to project baseline and controlled emission levels also has its strengths and weaknesses. However, the

model appears to have certain biases in its overall projections. More specifically, in July 2001 the U.S. National Research Council conducted an evaluation of the criteria and methodology for evaluating I/M programs including the use of the MOBILE model. On the basis of evaluations by states and by independent researchers, the committee found that the model may overestimate I/M program benefits. Nevertheless, it is the only model that can be used to project future years emissions reductions for various future program options.

4.3.1 Modeling Inputs

Several types of input are required for MOBILE6.2C to effectively evaluate the impact of each option on emission reductions. Data input to the model, along with the sources of the data, are summarized below.

- *Mileage Accumulation Rates (MAR)* – MAR used in previous MOBILE analyses were provided by the MOE. The MAR were based on analyses performed by Stewart Brown Associates, and applied to the Province of Ontario as a whole.
- *Speed VMT* – The Speed VMT file has been modified to reflect Ontario conditions, based on Appendix A of Part1F of the CW Consulting report provided by the Ministry.
- *Registration Distribution* – This data, by model year and program phase, was obtained from analysis of January 2005 MTO data, and is applied to each of the calendar years modeled. Note that a uniform registration distribution factor was used for light duty trucks (LDT1 – LDT4) and heavy duty vehicles (HDV2B – HDV8B), as individual factors for each vehicle class were not available from the data.
- *Diesel Fraction* – Similarly, the diesel fraction, by model year and program phase, was obtained from analysis of January 2005 MTO data, and is applied to each of the calendar years modeled. Note that a uniform diesel fraction factor was used for light duty trucks (LDT1 – LDT4) and heavy duty vehicles (HDV2B – HDV8B), as individual factors for each vehicle class were not available from the data.
- *I/M Program* – The Base Case I/M program contained EPA final ASM 2525 cutpoints for light-duty vehicles, and 2500/idle (low idle) cutpoints for heavy-duty vehicles. Model years less than twenty years old were subject to the program, with the exception of the three most recent model years. I/M compliance was set at 98.7%, and I/M waiver rates were set at 1.6%, consistent with MTO data. Deviations from the Base Case I/M run were modeled as separate scenarios, as specified in Table 4-2.
- *Seasonal Temperatures* – Minimum and maximum temperatures, varying by season, were obtained from Appendix B of Part1F of the CW Consulting report provided by the Ministry.

- *Fuel Sulphur Content* – Sulphur levels were obtained from Appendix K of Part1F of the CW Consulting report provided by the Ministry.
- *Fuel Composition Data* – Other data characterizing fuels, including Reid vapor pressure (RVP), aromatic, olefin, and benzene percentages, E200 and E300 values, and oxygenate levels were obtained from Appendix K of Part1F of the CW Consulting report provided by the Ministry.

4.3.2 Post-Processing of MOBILE6.2C Outputs

In order to calculate total kilotonnes per year of emissions from MOBILE6.2C emission factors, other additional information was applied to the data. These are summarized below.

- *Vehicle Kilometers Traveled (VKMT)* –Projected VKMT traveled for the whole of Ontario, by vehicle type and calendar year, were obtained from Appendix M of Part1F of the CW Consulting report provided by the Ministry. These VKMT were apportioned by phase, using vehicle population proportions supplied in Appendix H in the same report. After this adjustment, the VKMT were applied to emission factors derived from MOBILE6 modeling to calculate pollutant emissions in tonnes.
- *Inclusion of HDGV2B as light-duty trucks* – MOBILE6.2C treats vehicles with a GVWR of up to 8,500 lbs as light-duty trucks. Vehicles with a GVWR of 8,500 to 10,000 lbs are classified as heavy-duty (HDGV2B). As this is not consistent with Ontario's vehicle classification for testing, ERG treated HDGV2B vehicle emissions as light-duty truck emissions. In addition, to simulate the effect of ASM 2525 I/M on HDGV2B vehicles, ERG applied a ratio of non-I/M to I/M emissions from LDT4 vehicles to HDGV2B vehicles for each scenario of interest.

To obtain annual average emissions for each scenario, factors provided by the MOE were applied to emissions obtained from each seasonal run, in a fashion consistent with past modeling conducted for the Ministry:

Weighted Annual Emissions = (2*1.105*spring emissions +
3*1.136*summer emissions +
2*0.958*fall emissions +
5*0.893*winter emissions) /
(12 months)

It should also be noted that the standard MOBILE6.2C emission factors, provided in grams per mile, were converted to grams per kilometer to be consistent with the VKMT calculations.

4.3.3 MOBILE Reduction Estimates -- Base Case I/M

The future year effectiveness of the Base Case I/M program relative to the non-I/M program case was determined by calculating the difference between the total emissions of the two scenarios for a variety of pollutants. Table 4-3a presents the relative reduction for criteria pollutants. Figure 4-1 shows the emission levels with and without I/M, for VOC, NOx, and CO/7 in graphical form. Table 4-3b presents the same for toxic pollutants.

In the SBA analysis, ASM emissions were converted to mass emissions using the HOT 505 test data, before and after repair HOT 505 emission levels were grouped by ASM failure mode (pollutant and concentration) by model year and vehicle type, and these emission categories were multiplied by the appropriate number of vehicles in each failure mode, vehicle type and model year group from the *Drive Clean* test result data. The SBA approach used Drive Clean specific cutpoints to develop the failure mode bins; the MOBILE model only allows phase-in and final ASM cutpoints. The SBA approach also assigned additional emissions reductions for the idle portion of the Drive Clean test.

ERG's approach using MOBILE6 methodology is based on emissions benefits from I/M programs around the US. This data was also collected before 2000. The SBA estimates are for 1999 to 2003 and the MOBILE estimates are for 2005 onwards. If one compares the SBA 2003 estimate with the MOBILE6 2005 estimate there is no clear reason for the two methodologies to show similar emissions reduction benefits for CO and NOx but not for HC. Each method estimates the Ontario fleet emissions reductions based on emissions relationships developed under different testing scenarios.

Regardless of any difference between these two calculation methods, it is clear that the current program is producing substantial reductions in ozone precursor emissions (HC and NO_x), as well as large reductions in CO emissions.

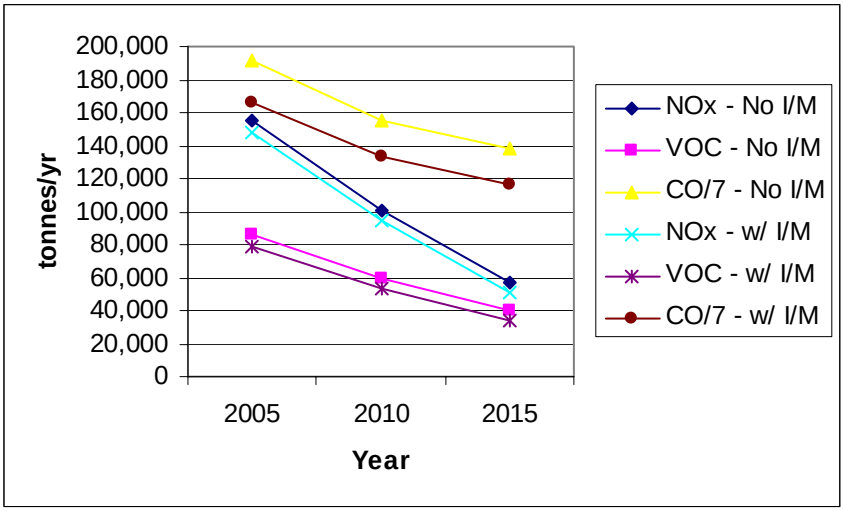
Table 4-3a. Base Case Criteria Pollutant Emission Reductions, Light-Duty Program (tonnes/year)

	HC	CO	NOx	HC+NOx	HC+NOx+CO/7
2005	7,502	174,662	7,371	14,873	39,825
2010	6,647	159,456	6,390	13,037	35,816
2015	6,225	153,732	6,514	12,739	34,701

Table 4-3b. Base Case Toxic Emission Reductions, Light-Duty Program (tonnes/year)

	Benzene	1,3 Butadiene	Formaldehyde	Acetaldehyde	Acrolein
2005	348	38	82	35	5
2010	297	33	73	32	4
2015	288	32	71	31	4

Figure 4-1. Projected Emissions with and without I/M



Model input files and raw output files, as well as spreadsheets summarizing model output from all scenarios and calendar years, will be provided electronically in CDROM format in a separate submittal.

4.4 Light-Duty Cost-Effectiveness Calculations

4.4.1 Methodology

ERG used data on DCF testing and repair costs, and the number of DCFs and tests conducted, to estimate the total costs of the base case program. Separate costs were estimated for the program to date (1999 – 2003), and future evaluation years (2005, 2010, and 2015). In both

cases costs were estimated for capital and operating expenses, including the following categories:

- Test equipment (options for up-front purchase and lease evaluated separately)
- Repair equipment
- Accreditation (start up and annual)
- Inspector and technician certification and re-certification
- DCF one-time deposit (cost due to lost interest)
- Annual equipment service contracts
- Consumables (e.g., calibration gases)
- Inspector and technician labor[8]
- Repair parts
- Incremental overhead
- Dedicated phone line
- Annual technical reference updates
- Government operations and contract costs

The majority of these cost estimates were derived from the KPMG report (KPMG 2003). Non-monetary costs such as motorist inconvenience were not included in the analysis. Government costs were obtained directly from the Ministry.[9] All operations and contract costs were attributed to the light-duty program, with the exception of the HDV QA/QC support contract. (Note that the light duty program comprises the vast majority of vehicles tested in the program.)

Note that motorist fees were not explicitly included as a line item in the cost analysis for the light-duty vehicle program. Since the light-duty program has a fee cap at $35, the fee itself may not cover all testing costs incurred by DCFs. Therefore ERG estimated testing costs using a "bottom-up" approach, calculating required inspector time based on DCO test volume data, and applying wage estimates. Equipment costs were also included, based on lease and operation cost estimates, combined with the number of certified DCFs by year. The test fees were excluded from the analysis to avoid double counting. In this way, a complete accounting of all DCF costs

[8] Analysis attributes labor costs to program only for actual test and/or repair time – any down-time is assumed to be redirected to other non-DC related activities.

[9] Historical and projected future year government expenditures represent *fiscal year* costs, and therefore differ slightly from the calendar year costs used for the other categories in this analysis. This inconsistency should have a negligible impact on final cost-effectiveness estimates.

was attempted. (ERG also performed a "top-down" calculation of program costs, using motorist fees and estimated repair costs as the basis, as discussed in Section 4.4.2 below.)

ERG estimated costs on a per-DCF basis, using historical and projected test and fail volumes, as well as the number of certified test and repair DCFs by year. (Note that ERG only modeled test and repair facility operations, since Test-Only facilities comprise less than 5% of the total number of certified DCOs). Historical vehicle test volumes and dispositions were taken from previous analyses of the *Drive Clean* program such as SBA.

The number of certified test and repair DCFs from 1999 through 2005 was obtained from the DCO Web Registry (current through May 23, 2005). Based on recent downward trends in the number accredited stations, ERG assumed the number of DCFs in future years would remain constant at 2005 levels (~1,400). Average per-station test and repair volumes were then derived for each calendar year, based on this data. ERG estimated per-station test and repair costs using the average vehicle test and repair volumes, and then estimated total program costs by multiplying by the expected number of participating DCFs in each year. Per-station test and repair volumes were assumed to hold constant at 2003 levels for the purpose of calculating future year program costs.[10]

Costs were increased for future years assuming a 2% annual inflation rate, and then discounted using a 5.9% real rate to obtain net present values (for the historical evaluation period of 1999 – 2003). Capital and other one-time costs were annualized for the future year projections (2005, 2010, and 2015), assuming a 7-year equipment life, and a 10% financing rate. Note that possible replacement costs for equipment were not estimated for future year cases. Final historical costs were scaled to 2005 Canadian dollars using national CPI values obtained from the Bank of Canada.

4.4.2 Base Case Cost Inputs and Calculations

For the light-duty program, bottom-up equipment and labor costs were derived from the KPMG 2002 Report.[11] Low, middle, and high ranges were calculated to gain a perspective on possible costs, but ultimately the middle range was chosen as most representative of costs for further analysis. The range of equipment costs, including installation is summarized in Table 4-4.

[10] This approach assumes that the number of DCFs remains constant, and that fail rates remain constant at 2003-4 levels. Deviations from these assumptions could impact overall program costs significantly.
[11] Financial Assessment of *Drive Clean* Facilities, KPMG, March 1, 2002.

Table 4-4 Light-Duty Equipment Costs

Range	Test Equipment Purchase	Test Equipment Lease (per month)*	Repair Equipment	Service Contract per year	Consumables**	Annualized Repair Equipment Costs (7 yrs at 10%)
Low	$50,000	$1,300	$8,000	$3,500	N/A	$1,643
Mid	*$65,000*	*$1,450*	*$10,000*	*$4,000*	*$1,500*	*$2,054*
High	$85,000	$1,600	$35,000	$4,500	$3,000	$7,189

* For leases lasting 4-5.5 years.
** Largely a function of test volume.

Hourly labor costs are detailed in Table 4-5, and include a 25% benefit loading factor. For test volumes of less than ten per day, one inspector and two technicians were assumed to be on staff. Inspectors and technicians were assumed to be working on non-*Drive Clean* activities during downtimes. It was also assumed that in the first two years of testing in a given Phase, vehicles would require an average of 3.2 hours to repair, and 2.3 hours to repair thereafter, consistent with the KPMG 2002 Report.

Table 4-5. Light-Duty Labor Costs

Range	Test Only Inspector Cost	Test and Repair Inspector Cost	Test and Repair Technician Cost
Low	$11.25	$12.00	$22.00
Mid	$13.80	$16.25	$31.25
High	$16.25	$30.00	$50.00

Historical *Drive Clean* light-duty test volume statistics were obtained from a prior program evaluation conducted by Stewart Brown Associates for light-duty vehicles during the 1999-2003 calendar years. The statistics from that evaluation are summarized in Table 4-6.

Table 4-6. Historical Light-Duty Inspection Statistics

Phase 1	Inspected	Fails	Re-insp.	Passed	Waived	Failed retest
1999	946,478	154,918	129,402	81,069	29,106	43,352
2000	1,250,837	174,943	144,105	96,378	36,170	36,143
2001	1,254,828	155,042	119,103	87,014	23,793	30,834
2002	1,312,488	140,956	101,233	79,361	14,416	27,841
2003	1,319,088	143,884	104,665	77,984	16,279	28,673
Phase 2	**Inspected**	**Fails**	**Re-insp.**	**Passed**	**Waived**	**Failed retest**
2001	788,875	111,599	91,166	50,351	36,126	20,414
2002	792,037	101,215	82,591	48,884	30,357	17,028
2003	808,142	95,312	73,857	52,505	15,455	20,052
Phase 3	**Inspected**	**Fails**	**Re-insp.**	**Passed**	**Waived**	**Failed retest**
2002	276,910	36,169	28,860	16,002	11,458	6,961
2003	467,559	59,258	50,764	27,375	20,715	10,892

Statistics on light-duty test-and-repair *Drive Clean* facilities (DCFs) were obtained from the DCO Web Registry[12] on May 23, 2005. These include the number of test-and-repair DCFs in the province, along with daily tests and repairs conducted. The figures provided are calendar year totals. Beyond 2005, the numbers of DCFs are assumed to hold constant at 2005 levels. Also, due to uncertainty regarding daily test and repair rates per facility, these rates were assumed to hold constant in the future at 2003 levels. In addition, since test-only DCFs made up only a small fraction of overall DCFs, they were not included in this analysis. DCF facility statistics are summarized in Table 4-7.

Table 4-7. DCF Light-Duty Test-and-Repair DCF Statistics

Year	New Yearly Test and Repair Facilities*	Tests per Day**	Repairs per Day**
1999	590	7.30	1.13
2000	208	6.90	0.87
2001	132	9.53	1.08
2002	233	8.75	0.87
2003	59	9.08	0.91
2004	72	9.08	0.91
2005	83	9.08	0.91
2006 - 2015	0	9.08	0.91

*Starting in 2006, no further increase as per DCO projections.
** 2004+ held constant at 2003 levels

Given the inputs listed above, light-duty vehicle program costs were calculated on a per-facility basis. Historical 1999-2003 costs were determined, as well as projected costs for 2005,

[12] DCO Web Registry, secure password-protected URL, 2005.

2010, and 2015. For the purposes of this analysis, any benefit from fuel economy was assumed to be zero, based on a recent SBA analysis which found the fuel economy benefits from repairs in the British Columbia ASM program are quite variable and average close to zero[13]. One-time and annual costs were considered separately, and equipment liquidation values were applied for the historical analysis. Annualized costs were used for the future year projections.

Total program costs were computed using three different methods.

- Method 1 assumed purchase of test equipment, with repair costs calculated from labor and parts estimates;
- Method 2 assumed lease of test equipment, with labor and parts costs;
- Method 3 assumed purchase of test equipment, with repair costs calculated from reported averages.

Tables 4-8 and 4-9 present historical and projected costs, respectively, using the bottom-up calculation methodology described above.

Table 4-10 provides a summary of the annual costs of the program in 2003 to the DCFs, the Government, and motorists. As seen in the table, variable costs dominate fixed costs for DCFs under the given cost assumptions, meaning that DCF profits are particularly sensitive to test and repair volumes. The split between test and repair costs for motorists is roughly similar, although repair costs are only borne by a relatively small portion of the public (see Table 4-11 for numbers of failing vehicles). This information allows a more meaningfully assessment the incremental impact of potential program options on the different *Drive Clean* constituencies.

Table 4-11 provides an indication of the overall scale of the program, showing the anticipated number of vehicles tested, the number of failures, and modeled reductions for 2005.

4.4.3 Cost-Effectiveness of Light-Duty Program

Using emission reductions derived from the MOBILE model along with calculated costs, light-duty cost effectiveness numbers were derived from comparing the “no I/M” scenario with the base case I/M program. Calculated cost effectiveness is provided in Tables 4-12a and 4-12b in 2005 Canadian dollars per tonne, for both the historical and projected cases. Table 4-12a provides results in terms of tonnes of HC+NOx+CO/7, corresponding to the “impact-weighted” reductions used in the British Columbia program analysis, while Table 4-12b uses HC+NOx

[13] Stewart, S.J., D.I. Gourley, and J. Wong. 2001. "AirCare: Results and Observations Relating to the First Eight Years of Operation (1992-2000)." Pacific Vehicle Testing Technologies Ltd.

alone. Of course the smaller denominator in Table 4-12b results in higher dollar-per-tonne values.

The future year projections shown in the table indicate a slow but progressive increase in the cost-per-tonne of the base case program over time. This increase in dollar per tonne values is due to fleet-turnover effects, wherein new vehicles meeting ever-tighter emission standards replace older, dirtier vehicles. Hence the absolute level of emission reductions possible continually declines over time, even if costs remain approximately the same per vehicle.

The table also shows somewhat lower dollar per tonne estimates using the SBA emission reductions than using ERG's modeled emission reductions, primarily because the MOBILE model estimates HC reductions to be about 45% of those estimated by SBA.

Table 4-8. Historical Light-Duty Program Costs

	1998	1999	2000	2001	2002	2003	
One-Time Costs							
Test Equipment	$38,350,000	$13,520,000	$8,580,000	$15,145,000	$3,835,000		
Repair Equipment	$5,900,000	$2,080,000	$1,320,000	$2,330,000	$590,000		
Accreditation	$590,000	$208,000	$132,000	$233,000	$59,000		
Inspector Certification	$117,410	$41,392	$26,268	$46,367	$11,741		
Tech Certification	$411,820	$145,184	$92,136	$162,634	$41,182		
Deposit	$295,000	$104,000	$66,000	$116,500	$29,500		($611,000)
Liquidation Value - Test							($35,759,286)
Liquidation Value - Repair							($5,501,429)
Annual Costs							
Service Contract*			$2,455,344	$3,387,376	$4,026,648	$5,136,184	
Equipment Lease option**		$10,471,320	$14,446,162	$17,172,468	$21,904,314	$23,475,849	
Consumables		$902,700	$1,245,359	$1,480,385	$1,888,303	$2,023,780	
Inspector Labor		$14,841,016	$19,355,711	$31,802,133	$37,232,784	$41,389,777	
Technician Labor		$17,620,908	$18,753,002	$27,752,393	$28,631,846	$31,897,226	
Repair Parts		$16,387,444	$17,440,292	$33,136,358	$34,186,424	$38,085,287	
Incremental Overhead		$3,009,000	$4,151,196	$4,934,617	$6,294,343	$6,745,934	
Annual Accreditation		$59,000	$79,800	$93,000	$116,300	$122,200	
Dedicated Phone Line		$421,260	$581,167	$690,846	$881,208	$944,431	
Reference and Standard Books		$2,124,000	$2,872,800	$3,348,000	$4,186,800	$4,399,200	
Inspector Re-certification		$117,410	$41,392	$26,268	$46,367	$11,741	
Tech Re-certification				$88,500	$31,200	$19,800	
Government Costs***		$16,931,400	$25,084,400	$22,049,800	$21,785,000	$21,300,000	
Total Costs (Method 2, Nominal $)	**$7,314,230**	**$85,464,035**	**$108,143,029**	**$148,850,645**	**$161,942,959**	**$175,551,409**	**($6,112,429)**

*Assumed to start in year 2 after warranty expires
**Mutually exclusive of One-Time Test Equipment costs
***Obtained from DCO - fiscal rather than calendar year basis, less HDDV contract costs

Table 4-9. Projected Light-Duty Program Costs

	2005	2010	2015
One-Time Costs			
Repair Equipment	$2,828,434	$3,268,854	$3,504,147
Accreditation	$22,627	$32,383	$16,785
Inspector Certification	$4,503	$6,444	$3,340
Tech Certification	$15,793	$22,603	$11,716
Deposit	$11,313	$33,584	$8,393
Annual Costs			
Service Contract*	$5,343,686	$6,199,166	$7,247,650
Equipment Lease option	$24,424,274	$28,555,225	$33,549,504
Consumables	$2,105,541	$2,461,657	$2,892,199
Inspector Labor	$43,061,924	$50,345,117	$59,150,426
Technician Labor	$33,185,874	$38,798,701	$45,584,554
Repair Parts	$39,623,933	$46,325,649	$54,427,957
Incremental Overhead	$7,018,469	$8,205,524	$9,640,662
Annual Accreditation	$122,200	$129,400	$137,700
Dedicated Phone Line	$982,586	$1,148,773	$1,349,693
Reference and Standard Books	$4,399,200	$4,658,400	$4,957,200
Inspector Re-certification	$11,741	$14,328	$16,517
Tech Re-certification	$19,800	$34,950	$8,850
Government Costs**	$19,701,000	$21,751,496	$24,015,409
Total Costs (2005 Canadian $)	**$182,882,897**	**$191,565,052**	**$201,685,280**

*Assumed to start in year 2 after warranty

**From DCO for fiscal year 2005, less HDDV contract costs, with 2% inflation factor applied for future years

Table 4-10. 2003 Calendar Year Program Costs and Revenues (Millions, 2005 Canadian $)

DCF Costs		Government Costs	Motorists Costs		Program Revenue	
Fixed*	Variable**	Total^	Tests	Repairs	To DCFs^^	To Gov't
43.5	118.5	21.3	99.8	120.1	189.5	30.6

Assumptions: Number of Initial Tests – 2,594,789
Number of Re-tests – 229,287
Number of Repairs[14] - 288,904
Average Cost per Repair – $398 (SBA 2002)

* Fixed DCF costs include: equipment lease; service contract; repair equipment purchase; incremental overhead; annual accreditation; dedicated phone line; reference and standard manuals; inspector and technician certification and re-certification.
** Variable DCF costs include: consumables; inspector labor; technician diagnostic and repair labor; repair parts
^ Net of HDV contract costs
^^Includes test fees and repair revenue

Table 4-11. Impact of Base Case Program on Subject Fleet and Emission Reductions - 2005

Model Year	# of Vehicles*	% of Fleet[15]	Failure Rate	Failing Vehicles	Emissions Reductions (Tonnes/Yr)		
					HC	CO	NOx
Base	2,292,222	37.8%	9.8%**	211,801	7,502	174,662	7,371

* From DesRosiers 2005
** 2005 fail rate derived from ERG by-model year analysis of 2003-2004 biennial data

[14] Assumed equal to # of re-tests plus # of re-test fails
[15] Derived from DesRosiers Report – 2005 test fleet as percentage of total biennial fleet (all model years, all phases).

Table 4-12a. Cost-Effectiveness for Light Duty Program ($/tonne HC+NOx+CO/7)

	SBA Basis	M6.2C Base Case		
	Historical (99-03)	2005	2010	2015
Method 1	$3,275			
Method 2	$3,387	$4,640	$5,414	$5,882
Method 3	$4,125			

Table 4-12b. Cost-Effectiveness for Light Duty Program ($/tonne HC+NOx)

	SBA Basis	M6.2C Base Case		
	Historical (99-03)	2005	2010	2015
Method 1	$7,284			
Method 2	$7,533	$12,423	$14,873	$16,023
Method 3	$9,175			

The tables also show the results of a sensitivity analysis performed by ERG for the historical program, evaluating the potential impact of different assumptions on large, uncertain cost components (test equipment and repairs). First, ERG estimated the costs for both up-front equipment purchase and monthly lease, both arrangements being common in the testing industry. ERG also used different sources of information to estimate repair costs – one scenario developed bottom-up estimates from technician labor rates, repair times, and parts costs (from KPMG 2002), while another utilized reported repair costs from the DCO's Vehicle Emissions Transactions System (VETS). The resulting range is relatively tight, lending confidence to our general conclusions regarding cost-effectiveness. ERG adopted "Method 2" (equipment lease plus bottom-up repair costs, which resulted in the mid-range cost estimates), as the basis for future projections and option evaluations.

Finally, ERG performed a "top-down" cost-effectiveness calculation using motorist test fees and repair costs as an independent check on the above estimates. The findings are again quite similar to the Method 2 results shown above. Table 4-13 summarizes the key elements of the top-down calculation.

Table 4-13. Alternative Top-Down Cost-Effectiveness Calculation

	2003+ Test Fees/Vehicle		
Result	Gov't	DCF	Total
Pass	$11.67	$23.33	$35.00
Fail	$0.00	$35.00	$35.00
Retest Pass	$11.67	$5.83	$17.50
Retest Fail	$0.00	$17.50	$17.50
Conditional Pass	$11.67	$5.83	$17.50
2005 Annual Fees			**$173,765,180**
Average Repair Cost/vehicle			$398
2005 Total Number of Fails			217,318
2005 Total Repair Costs			**$89,987,045**
Historical $/tonne (HC+NOx+CO/7)			**$3,698**
2005 Projected $/tonne (HC+NOx+CO/7)			**$4,363**

4.4.4 Environmental and Social Impacts of Light-Duty Program

The *Drive Clean* program is providing significant improvements to local and regional air quality by reducing the health impacts associated with exposure to ground-level ozone, carbon monoxide, toxic chemicals such as benzene, and fine particulate matter from diesels. The program's significant emissions reductions would be expected to decrease both the mortality and morbidity impacts associated with local and regional air pollution as a whole. Other environmental benefits include potential improvements to visibility (from PM), reduced damage to crops (from PM and NO_x), and general improvements in outdoor recreation of all kinds. Improvements in all of these areas enhances overall quality of life in the Ontario region.

At this time there is some evidence that the light and heavy-duty vehicle components of the *Drive Clean* program may produce slight benefits in vehicle fuel economy. However, these benefits are expected to be on the order of less than 1% and were not explicitly quantified for this study (see Section 4.4.2 above). Accordingly, there may be a small but unquantified reduction in greenhouse gas (CO_2) emissions associated with the program.

The introduction of the *Drive Clean* program also has had several hard to quantify, but quite real "social impacts" across the region, all of which should be considered for the long-term success of the program. These include impacts on consumer protection, the perceived equity of the program, and motorist acceptance of the program in general.

Some general observations can be made regarding the social impacts of the *Drive Clean* program. First, like all effective I/M programs *Drive Clean* provides motorists with incentives for pre-test repairs and preventative maintenance that would not have been performed otherwise. Second, implementation of the *Drive Clean* program has strived to promote consumer protection in several ways. For instance, the certification process for repair technicians, the phase-in of higher repair cost limits, and the progressive tightening of ASM emissions cutpoints are all intended to help train private sector repair technicians over time, and to minimize opportunities for fraudulent repairs.

The relatively low repair cost limits and the provision allowing for unlimited conditional passes over time both tend to ease the burden on lower income motorists, who tend to own higher emitting vehicles. However, the recent increase in the repair cost limit (and additional proposed changes – see below), tends to increase the financial impacts on lower income participants, and may be perceived as inequitable. On the other hand, requiring those vehicles with the highest emissions to be repaired may be viewed as equitable by some, consistent with a "polluter pays" approach to emission reduction.

Finally, overall motorist acceptance of the program depends on a host of factors, including test fees, fail rates, repair costs, inconvenience, and the perceived need for and effectiveness of the program itself, as well as the equity and consumer protection issues noted above. A formal assessment of motorist acceptance was performed early in the program by Environics Research (2000) indicating 80% overall approval ratings. More recent data from the DCO Integrated Complaint Management System (ICMS) indicates low rates for complaints and disputes, also indicative of general approval. (See Section 5.5 for more details on the ICMS). Additional program adjustments designed to increase consumer convenience, and decrease out of pocket test and/or repair costs, would help maintain motorist acceptance of the program in the future.

4.5 Cost-Effectiveness Results of Other I/M Programs

ERG compiled additional cost-effectiveness estimates from the literature for other large-scale I/M programs operating in North America. As seen from the above section, there are a large number of different cost components, emissions modeling inputs, and methodological assumptions involved in the calculation of dollar per tonne estimates for test and repair programs. Not surprisingly then, the cost-effectiveness values reported for other programs each have different basis and cannot be compared directly to one another. However, large differences

between dollar per tonne values could possibly point to meaningful, qualitative differences in program performance and efficiency.

ERG identified cost-effectiveness values for four other large I/M programs for comparison with the *Drive Clean* estimates. These include California's enhanced program, the State of Arizona's Phoenix area program, the State of Colorado's testing program in Denver, and the ASM test program in Vancouver. Table 4-14 summarizes the major program components, calculation methods, and cost-effectiveness results for these programs.

Table 4-14. Cost-Effectiveness Values Reported for Drive Clean and Other Programs

Program (analysis Yr)	Test Type	Test Facilities	Fee Type	$/tonne[16]	Units	Cost Components
California Enhanced Smog Check (2002)[17]	ASM	Decentralized	Market	$7,123	$/HC+NOx	Fees, repairs, fuel savings
Arizona – Phoenix Area (2000) [18]	IM240	Centralized	Cap	$6,444	$/HC+3.33*NOx	Fees, repairs, fuel savings, inconvenience
Colorado - Denver [19] Area (2000)	IM240	Centralized		$17,952	$/HC+CO/60	Fees, repairs, fuel savings, inconvenience, removal from area
British Columbia AirCare (2003) [20]	IM240	Centralized	Cap	$7,000	$/HC+NOx+CO/7	Fees, repairs, fuel savings
Ontario Drive Clean	ASM	Decentralized	Cap	$4,640	$/HC+NOx+CO/7	Testing costs, repairs

In addition to substantial differences that can arise from various emission benefit calculation options, we can see several cost and reporting conventions that result in "apples to oranges" comparisons. For example, as noted earlier, the units used for reporting cost-effectiveness differ from program to program, reflecting area-specific air quality concerns. For instance, the Phoenix area is "NO_x -limited" with respect to ozone formation, and therefore

[16] All values converted to 2005 Canadian $ and metric tonnes
[17] California Air Resources Board April 2004.
[18] Transportation Research Board Special Report 264, pp 468-470.
[19] ENVIRON 2003.
[20] Levelton 2004.

places a premium on NO_x reductions relative to HC. This is reflected in its calculation of cost-effectiveness for its I/M program. Adjusting the Arizona estimates to be on equivalent terms with the *Drive Clean* evaluation would undoubtedly increase their dollar per tonne estimates substantially (although the summary reports obtained by ERG did not provide enough information to make these adjustments ourselves). Similarly, inclusion or exclusion of entire categories of costs (such as motorist inconvenience or removal of failing vehicles from the test area) also assuredly impact cost-effectiveness estimates significantly.

Based on the above information, however, we can conclude that the $/tonne estimates derived by ERG are roughly in line with those calculated for other I/M programs. However, the exact reasons for any differences cannot be determined without detailed comparisons with other program studies.

4.6 Heavy-Duty Test and Repair Program

As noted at the start of this section, there are great uncertainties associated with estimating the particulate matter reductions and costs associated with test and repair programs for heavy-duty vehicles. For these reasons ERG did not attempt to project PM reductions for future analysis years, nor did we estimate costs or cost-effectiveness. The following summarizes existing PM reduction estimates from previous evaluations.

Historical *Drive Clean* heavy-duty test volume statistics and emission reductions were obtained from a prior program evaluation conducted by GW Taylor Consulting[21] for heavy-duty vehicles during the 2000-2002 calendar years. The statistics from that evaluation are summarized in Table 4-15. The reductions themselves are expected to continue to decrease over time, primarily due to fleet turnover and the future introduction of dramatically lower PM emission standards for manufacturing.

Table 4-15. Heavy-Duty Inspection Statistics and Emission Reductions (PM)

	2000	**2001**	**2002**
HHDV+Bus (counts)	39,841	40,654	46,136
MHDV (counts)	56,330	57,480	61,189
LHDV+School Bus (counts)	26,547	27,089	29,512
Total (counts)	122,718	125,223	136,837
PM10 Reduction (tonnes)	**415**	**483**	**193**

[21] *Drive Clean* Program Emissions Benefit Analysis and Reporting – Heavy Duty Diesel Vehicles, G.W. Taylor Consulting, October 2003.

Statistics on heavy-duty test-and-repair DCFs were obtained from the DCO Web Registry. These include the number of both test-only and mobile facilities in the province. Failure rates were obtained from the *Drive Clean* test result database. Table 4-16 presents heavy-duty DCF facility statistics and failure rates.

Table 4-16. Heavy-Duty Facility Statistics

Calendar Year	Number of Mobile Stations	Number of Test Only Stations	Total Stations	Total Cumulative Stations	Failure Rate
1999	117	250	367	367	5.0%
2000	58	94	152	519	4.7%
2001	11	14	25	544	3.1%
2002	8	10	18	562	2.3%
2003	11	15	26	588	2.2%
2004	15	15	30	618	2.8%
2005	4	10	14	632	3.6%

Many of the vehicles subject to HDDV I/M spend a large fraction of their activity outside of the jurisdiction, hence some fraction of the emission reductions occur outside the I/M program jurisdiction. This situation is common to all programs designed to reduce HDDV emissions. (Note that the "reflash" measure assumes only 30% of total HDDV travel in the area is attributable to locally registered trucks – see Section 6 below.) Some jurisdictions, such as California, have implemented laws that require any HDDV driving within the jurisdiction to adhere to the same on-road emissions standards as locally registered vehicles. Ontario's regulation also requires HDDVs driving in the province to meet provincial on-road emissions standards.

The evaluation methods used to estimate HDDV I/M benefits are highly uncertain, but are the only means available for such assessments at this time. Therefore future evaluations should seek to develop improved methods for estimating emissions benefits.

Insufficient data currently exists to determine the impacts on emissions reductions from exempting additional HDV model years. A higher standard for these vehicles is justified, since they are predominantly commercial vehicles intensively used for profit, and must be should be extremely well maintained to remain low polluting. Any miscalculations in the design of a model year exemption policy could result a heavy air pollution penalty. This issue could be further studied in the proposed HDDV pilot study to determine the best approach for arriving at a decision on model year exemptions for this portion of the fleet.

5.0 Program Effectiveness Evaluation

In this section we examine how effective the *Drive Clean* program is in achieving its goals and objectives. The program has four performance objectives:

1) Effectively reduce emissions of smog-causing pollutants including NO_x, VOCs, and particulate matter (PM).
2) High degree of public acceptance.
3) Revenue neutrality over the life span of the program with full-cost recovery via testing and accreditation fees.
4) Business integrity. (The program is designed to achieve the highest standard of compliance with the Performance Contract at *Drive Clean* facilities.)

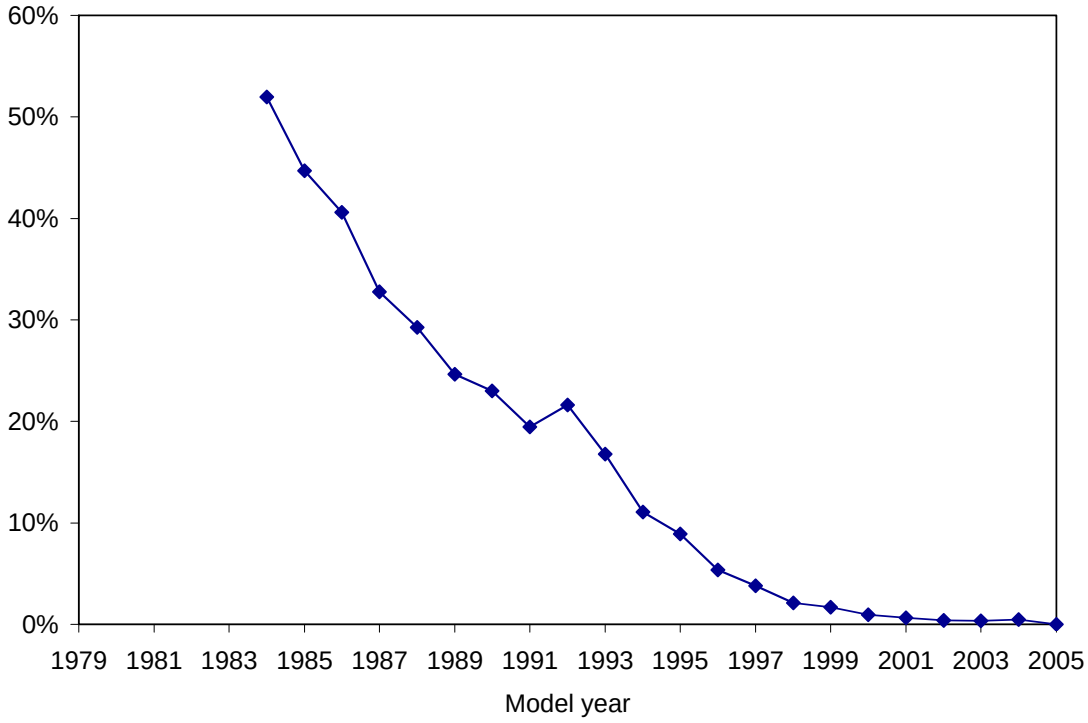
To assess the current effectiveness of *Drive Clean*, we compare the structure of the program with those in other jurisdictions, particularly decentralized programs using an ASM test similar to the *Drive Clean* test (California, British Columbia, Georgia, Texas, and Virginia), and centralized programs (Arizona and Colorado) that are considered model programs. As part of our assessment we studied several aspects of the *Drive Clean* program, using the official test results from inspections conducted at *Drive Clean* facilities.

5.1 LDV Program – Effectiveness Evaluation

5.1.1 LDV Program Statistics

In 2003-04, 9% of light-duty vehicles failed their initial *Drive Clean* test. Figure 5-1 shows the failure rates by model year for light-duty vehicles. The failure rates are much higher for older vehicles than for newer vehicles.

Figure 5-1. 2003-04 Light-Duty Vehicle Failure Rates, by Model Year



5.1.2 LDV Program – Strengths and Weaknesses Evaluation

This section describes the design and operational parameters of the *Drive Clean* light-duty vehicle program and assesses what aspects of the program are effective in reducing emissions, and what aspects can be improved. We also compare aspects of the *Drive Clean* program with those of other I/M programs.

5.1.2.1 Model Years

On average, newer model years have lower emissions than older model years because they are designed to meet more stringent emission certification standards when new. Emission controls for new and old vehicles deteriorate and become less effective as vehicles age. Although older model years have higher emissions than newer model years, there are fewer of them still on the road, and they tend to be driven less each year than newer model years, which affects their contribution to the on-road emission inventory. Because of natural turnover in the on-road fleet, when old model years are removed from the fleet and new model years added to the fleet, on-road emissions decrease over time. The inclusion of an I/M program should reduce emissions even further.

The *Drive Clean* program currently requires that the following vehicles be tested: all light-duty vehicles more than three and less than 20 model years old; all heavy-duty vehicles more than three model years old; all light-duty resale vehicles more than one and less than 20 model years old; and all heavy-duty resale diesels more than one model year old. Table 5-1 shows the model years of light-duty vehicles that were required to be tested in each of the years since the inception of the program; the model years in parenthesis are the newest model year of resold vehicles that were required to be tested. The model years of heavy-duty diesel vehicles required to be tested in each year are similar, except that there is no exemption for older heavy-duty diesels. Because heavy-duty diesels are tested annually, both even and odd model years are tested in each year. A small number of exempted and "off-cycle" vehicles are tested each year, either because they are in the process of changing ownership or they are first being registered in the Ontario area.

Table 5-1. Model Years Required to be Tested in *Drive Clean* Program, by Calendar Year

Year	Light-duty model years required to be tested (change of ownership)	Even or odd
1999	1980 to 1996 (1998)	even
2000	1981 to 1997 (1999)	odd
2001	1982 to 1998 (2000)	even
2002	1983 to 1999 (2001)	odd
2003	1984 to 2000 (2002)	even
2004	1985 to 2001 (2003)	odd
2005	1986 to 2002 (2004)	even

The *Drive Clean* program has a rolling model year exemption for 20-year-old and older vehicles; eight other jurisdictions have a rolling model year exemption for older vehicles (with either 25- or 26-year-old and older vehicles exempted). 23 jurisdictions exempt vehicles older than a specific model year; all but three of these test vehicles older than 1980. Three jurisdictions test vehicles of all ages. In terms of exemptions for the newest model years, 2 jurisdictions exempt the five newest model years, 9 jurisdictions exempt the four newest model years, and 16 exempt the one to three newest model years; 10 jurisdictions do not exempt any new vehicles from testing. Most I/M programs do not exempt more than the four newest model years in order to insure that vehicles get at least one emissions test before the manufacturer's warranty expires. Eight other programs also require an emissions test upon change in vehicle ownership. Some jurisdictions also require that otherwise-exempt model years be tested upon initial registration in the jurisdiction, regardless of age. California is justified in such a practice, as it tends to have stricter new vehicle emission certification standards than the rest of the U.S.; however, I/M inspections upon initial registration are less justified in other jurisdictions.

ERG analyzed whether fewer older and more newer model years of light-duty vehicles should be exempted from the program. Although there are fewer older than newer vehicles on road, particularly in Ontario with its colder weather and extensive use of road salt, and older vehicles are driven fewer kilometers per year on average than newer vehicles, they also have higher emission rates on average than newer vehicles. Previous research indicates that, on a weighted-weighted basis, older vehicles still represent the largest emission reductions per vehicle tested.

To analyze the effect of changing the model years currently exempted from the program, we estimated the mass emission reductions by vehicle type and model year. We made this estimate by comparing the initial and final ASM emissions of vehicles that failed their initial test and passed a subsequent retest (fail-pass vehicles). This analysis overstates the actual emissions reductions from the program, as emissions tend to increase, and emission reductions decrease, as soon as a vehicle passes a retest, for a variety of reasons; however, this simple analysis gives an indication of the fraction of total emission reductions available by vehicle model year. We convert ASM emissions expressed in concentrations to grams per gallon, based on the molar carbon fraction in the exhaust and gasoline (from equations initially derived to make similar conversions for remote sensing readings). Next we multiply the total grams per gallon of emission reductions by vehicle type and model year by estimates of average fuel use, to obtain emission reductions in terms of grams per kilometer. Finally, we multiply the gram per kilometer emission reductions by estimates of annual vehicle travel by vehicle type and model year, from US EPA's MOBILE6.2C model, to obtain emission reductions in tonnes by vehicle type and model year.

Figures 5-2 through 5-5 show the emission reductions per 10,000 vehicles tested, by vehicle type and model year (because of the odd-even model year cycle of testing, the number of vehicles tested in a given year fluctuates greatly by model year; therefore the figures show emission reductions for vehicles tested over a two-year period). This is a measure of the effectiveness of including particular model years in the *Drive Clean* program; even though the total emission reductions from a particular model year may be relatively small, the emission reduction per vehicle tested could be relatively large. Figures 5-2 and 5-3 indicate that the most benefits per car tested occur for 1983 to 1987 cars, for all three pollutants. Figures 5-4 and 5-5 indicate that the most benefits per light truck tested are from model years 1985 to 1992.

Figures 5-6 and 5-7 show the cumulative distribution of vehicles tested, and emissions reductions, for all light-duty vehicles tested in 1999-00 and 2003-04. The figures allow one to determine the contribution of the oldest and newest model years to the number of vehicles tested,

and emission reductions. For instance, 1996 and newer light-duty vehicles accounted for 50% of the vehicles tested in 2003-04, but only 5% of the emission reductions for each pollutant.

Figures 5-2 through 5-7 suggest that the rolling model year exemptions for the oldest model years in the *Drive Clean* program be ended. These older vehicles represent the most efficient emission reductions, in terms of reductions per vehicle tested, in the program. Similarly, the figures indicate that exempting more newer model year vehicles will have little effect on the reduction in emissions

Note that the emission reductions shown in Figures 5-2 through 5-7 are simple estimates based on the initial emission reductions of fail-pass vehicles only. The estimates do not include deterioration in emissions after repairs, nor do they include emission reductions from preinspection maintenance and/or repairs, repairs to conditional-pass vehicles, or permanent removal of no-final-pass vehicles from the *Drive Clean* area.

Figure 5-2. 1999-00 Phase 1 Initial Emission Reductions per 10,000 Cars Tested, by Model Year

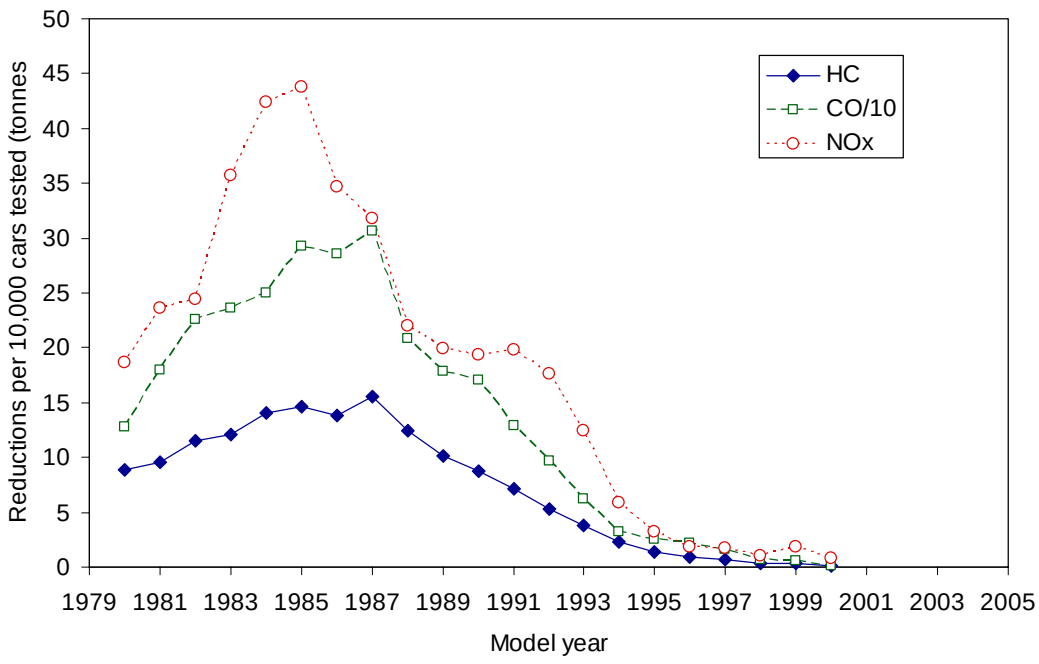


Figure 5-3. 2003-04 Phase 1 Initial Emission Reductions per 10,000 Cars Tested, by Model Year

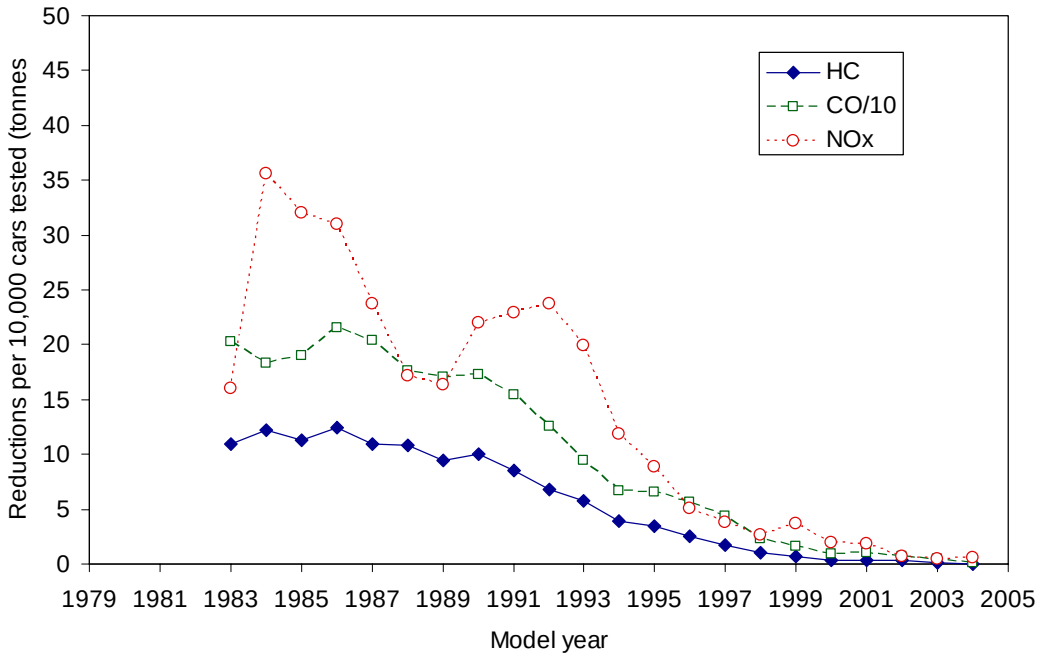


Figure 5-4. 1999-00 Phase 1 Initial Emission Reductions per 10,000 LDTs Tested, by Model Year

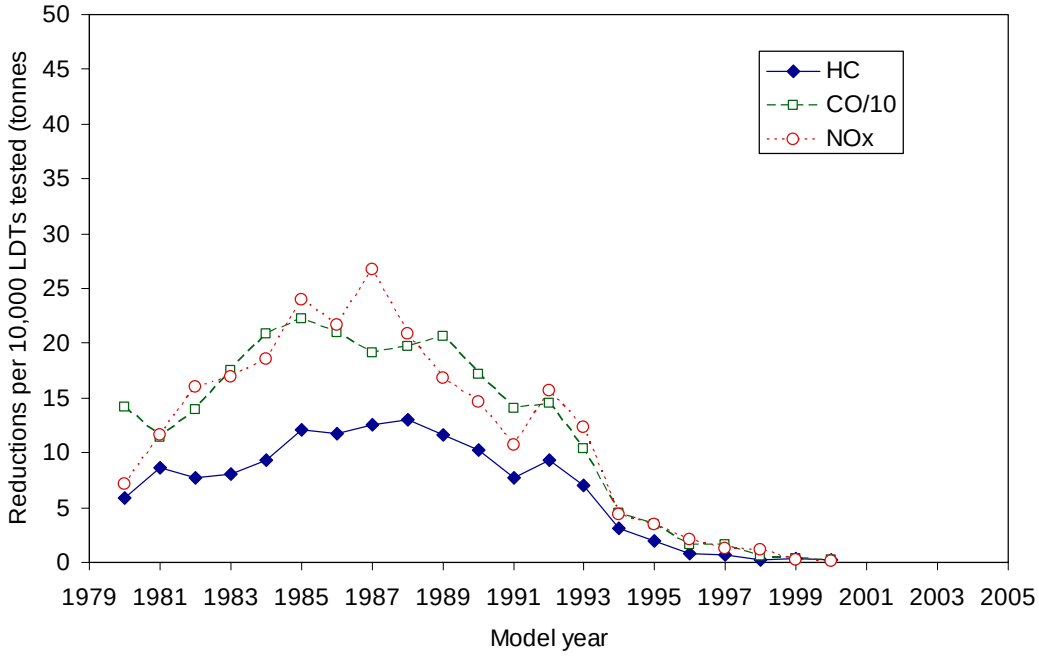


Figure 5-5. 2003-04 Phase 1 Initial Emission Reductions per 10,000 LDTs Tested, by Model Year

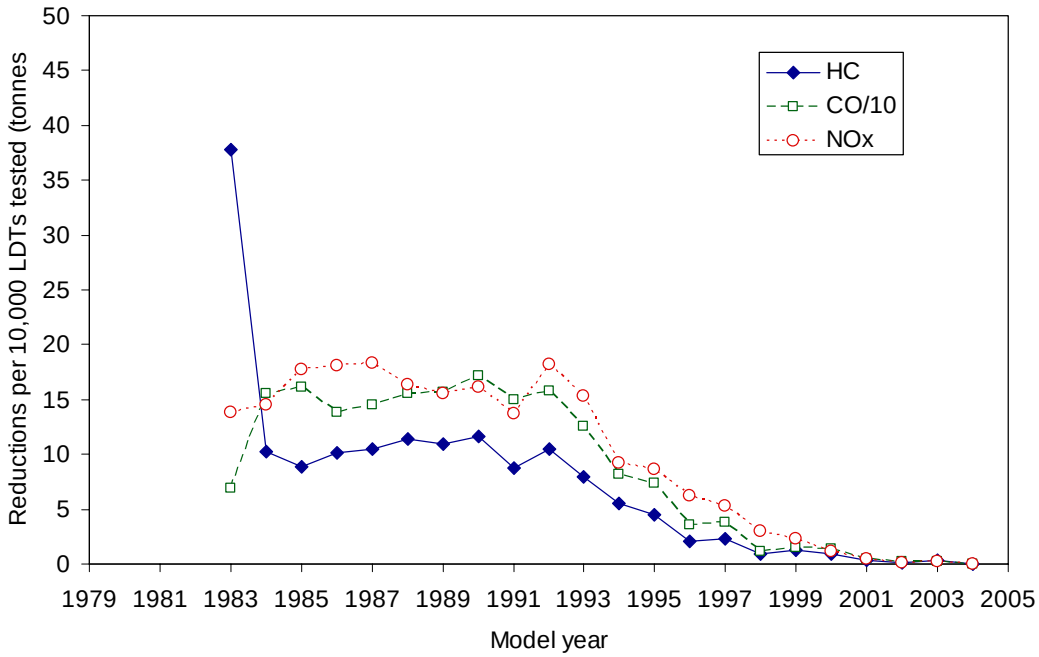


Figure 5-6. Cumulative Fraction of Phase 1 1999-00 Vehicles Tested and Emission Reductions, from Oldest to Newest Vehicles

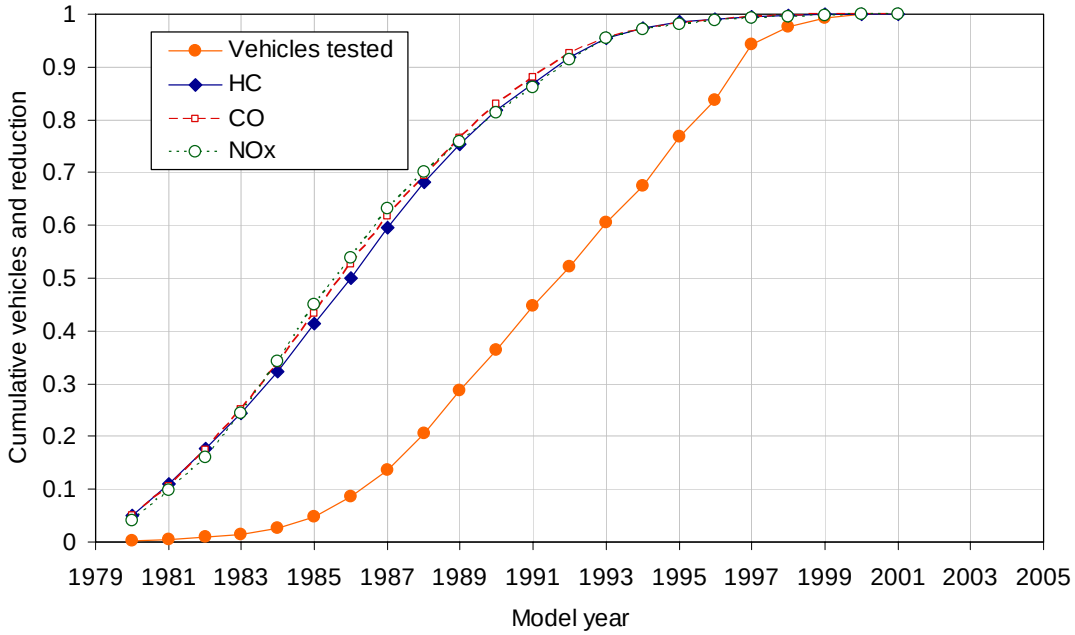
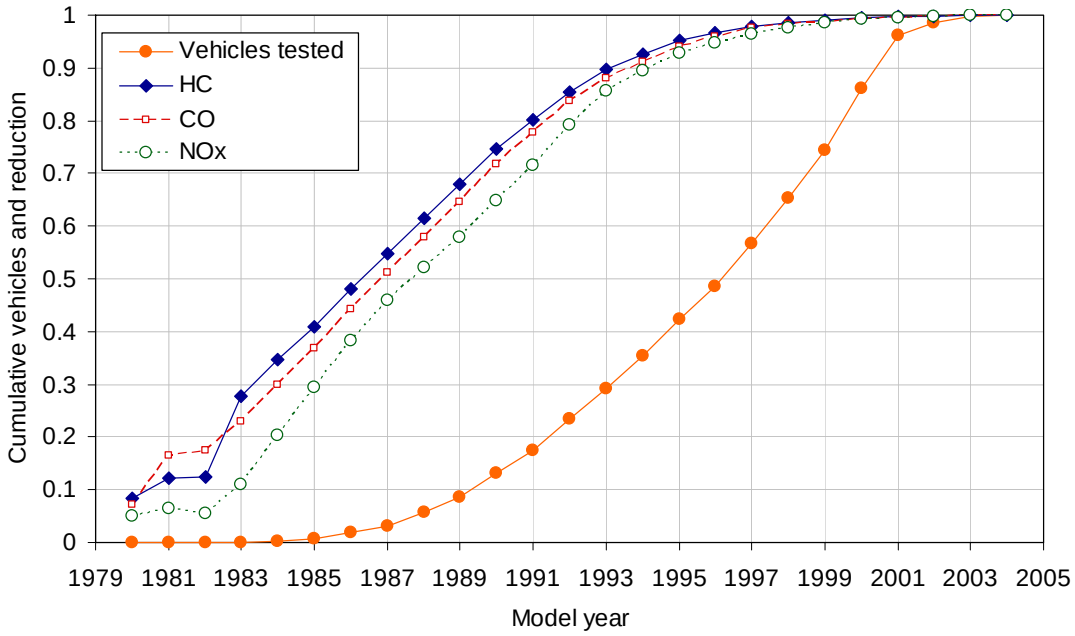


Figure 5-7. Cumulative Fraction of Phase 1 2003-04 Vehicles Tested and Emission Reductions, from Oldest to Newest Vehicles



We then estimated the potential emission reductions that could be obtained by including fewer or more model years in the *Drive Clean* program. We first took the number of vehicles registered in the phase 1 postal codes in Ontario, from the MTO registration database. Then we applied the emission reductions per vehicle tested from Figures 5-2 through 5-5 above to the model years currently exempted from the program. Then we combined these emission reductions with the estimated emission reductions for the model years actually tested, to derive new total emission reductions. Table 5-2 shows the estimated number of vehicles, and emissions reductions, of currently exempt and currently eligible model years.

Table 5-2. Number of Phase 1 Vehicles and Distribution of Estimated Excess 2003 and 2004 Emissions, by Model Year Group

Model years	Distribution of Vehicles	Distribution of 2003-04 estimated emission reductions		
		HC	CO	NO_x
Percent of on-road fleet:				
Currently exempt (MY80 and older)	0.5%	3.4%	3.1%	3.3%
Currently exempt (MY81-83)	0.4%	2.4%	2.2%	2.4%
Currently eligible (MY84-97)	42.2%	84.3%	81.7%	78.3%
Currently eligible (MY98-99)	13.2%	3.5%	4.2%	4.6%
Currently eligible (MY00-01)	15.9%	1.9%	2.5%	3.4%
Currently exempt (MY02-05)	27.7%	4.4%	6.4%	8.0%
Total	100.0%	100.0%	100.0%	100.0%
Percent of *Drive Clean* fleet:				
Currently eligible (MY84-97)	59.2%	94.0%	92.4%	90.7%
Currently eligible (MY98-99)	18.5%	3.9%	4.7%	5.4%
Currently eligible (MY00-01)	22.3%	2.1%	2.8%	3.9%
Total	100.0%	100.0%	100.0%	100.0%

We estimate that including all currently exempted older vehicles (1983 and older in 2004) would increase the number of vehicles tested by 1%, resulting in an additional 6% of reductions for all three pollutants (including only 1981 and newer vehicles would increase the number of vehicles tested by 0.4%, and increase emission reductions by 2% for all three pollutants). On the other hand, excluding the two newest model years that were eligible for testing in 2004 (2000 and 2001 vehicles) would remove 22% of the vehicles from the program while reducing emission reductions by only 2% for HC, 3% for CO, and 4% for NO_x. Exempting the four newest model years that were eligible for testing in 2004 (1998 to 2001 vehicles) would remove 41% of the vehicles from the program, while reducing emission reductions by 6% for HC, 7% for CO, and 9% for NO_x.

Our estimate of the emission reduction potential of the 1983 and older vehicles is sensitive to the assumptions used for emission reduction per vehicle tested (taken from Figures 5-2 through 5-5). However, our estimate gives an indication of the magnitude of the number of vehicles involved and the emission reduction potential.

5.1.2.2 Types and Classes of Tested Vehicles

The *Drive Clean* program requires that light-duty vehicles in the eligible model years be tested. Alternative fueled and diesel light-duty vehicles must be tested, while electric light-duty vehicles are exempt from testing. Vehicles with hybrid-electric drive were exempted from testing in the program in May 2005.

There also are 137,000 motorcycles, and 186,000 snowmobiles, registered in Ontario. Table 5-3 indicates that 86% of the motorcycles, and only about half of the snowmobiles, are registered in the *Drive Clean* program area. At least one jurisdiction (Arizona) currently includes motorcycles in its I/M program; California is considering adding motorcycles to their program.

Table 5-3. Number of Motorcycles and Snowmobiles Registered in Ontario in 2004, by Area

Vehicle type	Non-I/M areas	I/M areas	Total
Motorcycles	18,843 14%	118,173 86%	137,016 100%
Snowmobiles	93,229 50%	93,248 50%	186,477 100%

Four jurisdictions (Alaska, Arizona, Colorado, and New Mexico) require that vehicles registered outside of the I/M area but commute regularly into the area be tested as part of their program. Of these four, only two (Arizona and Colorado) include heavy-duty diesel vehicles in their I/M programs. However, it is not clear what fraction of eligible commuter vehicles actually participate in these I/M programs. On-road observations of vehicles, obtained using either remote sensing, pullover testing, or parking lot cameras, are needed in order to enforce such a requirement.

5.1.2.2 Program Area

The *Drive Clean* program area for light-duty vehicles has already been expanded twice, in January 2001 and July 2002 (all heavy-duty diesel vehicles registered in Ontario are subject to the program). We analyzed the number of light-duty vehicles tested and failure rates by county, to determine if there are substantial differences in failure rates by county. This required merging the vehicle test result data for 2003-04 by VIN with the registration database (which includes the county in which the vehicle is registered). We then grouped the counties by *Drive Clean* phase. Parts of 11 counties are in phase 2 and phase 3; we analyzed these counties separately.

Figure 5-8 shows the distribution of light-duty vehicles tested, by phase and county (the 11 counties in both phase 2 and phase 3 are shown on the right in violet). 16% of all tested vehicles were registered in Toronto, followed by Peel (9%), York (7%), and Ottawa (6%) Counties. Figure 5-9 shows the failure rate by phase and county; the failure rate in each county is normalized by the model year distribution of all vehicles tested. The figure indicates that there are no substantial differences in failure rates by county. Failure rates by county range from 10%

(Peel) to 8.4% (Halton) in the phase 1 counties, 9.6% (Brant) to 9.3% (Oxford) in the phase 2 counties, 10.6% (Prescott/Russell) to 8.3% (Prince Edward) in the phase 3 counties, and 10.0% (Perth) to 8.8% (Lambton) in the combined phase 2 and 3 counties.

Figure 5-8. Distribution of Light-Duty Vehicles Tested in 2003 or 2004, by Phase and County

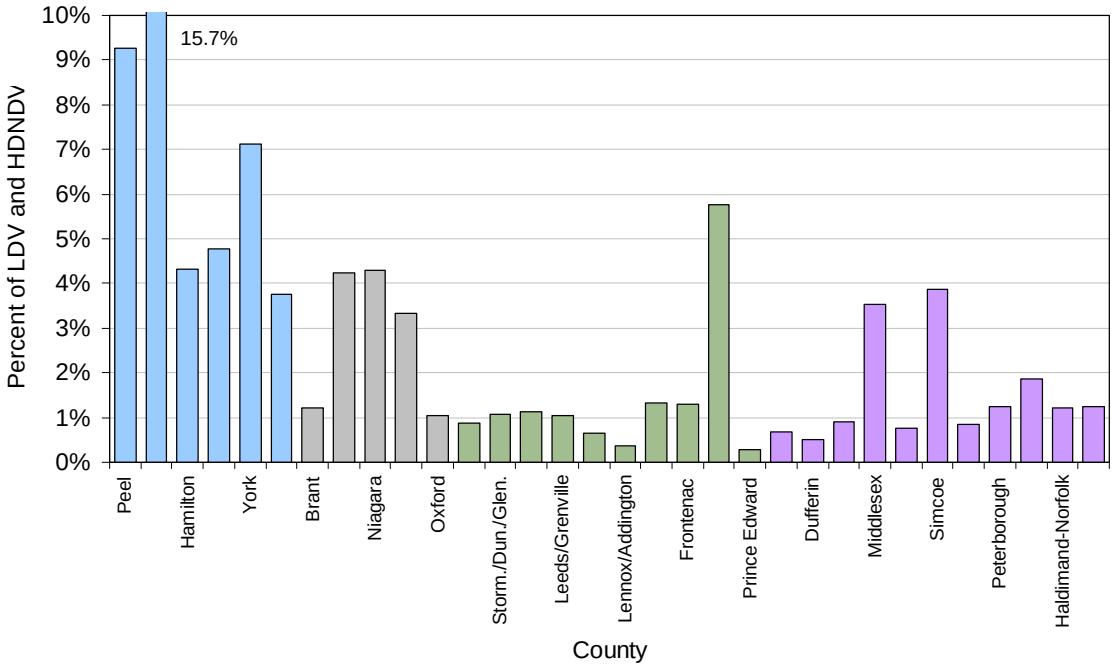
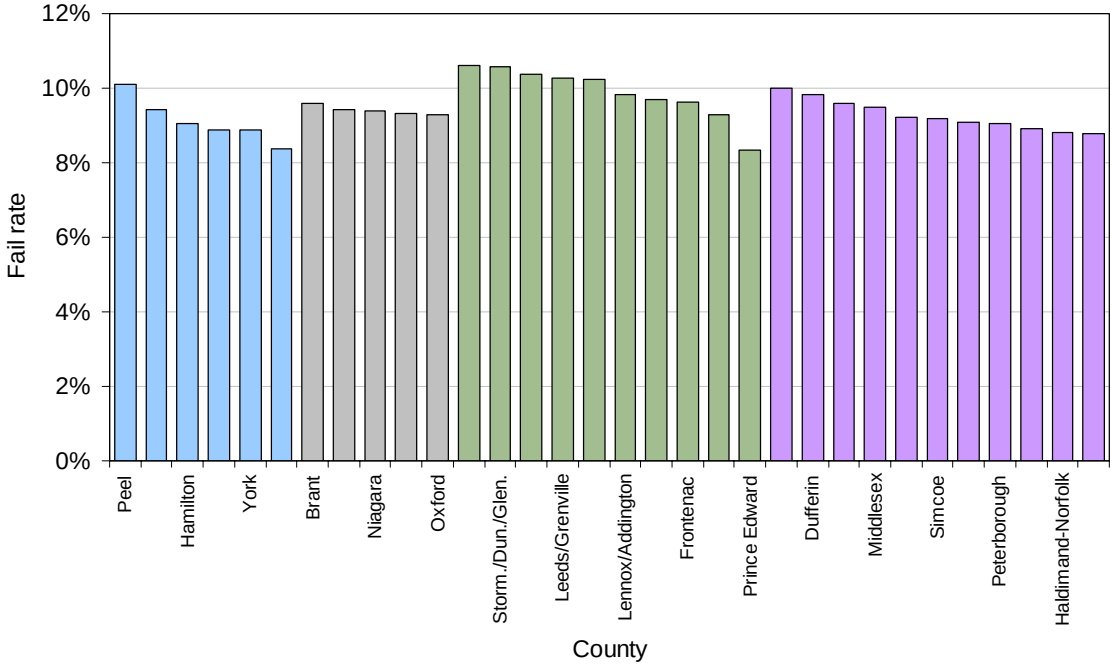


Figure 5-9. Fail Rates of Light-Duty Vehicles Tested in 2003 or 2004, by Phase and County



These differences in fail rates are not sufficient to justify excluding entire counties from the *Drive Clean* area.

5.1.2.3 Test Method – ASM

I/M tests are designed to identify vehicles with high emissions under certain conditions; they are not intended to estimate in-use emissions under varying conditions. Because large numbers of vehicles must be tested in an I/M program, often at a large number of test facilities (in decentralized programs), test conditions cannot be carefully controlled for every test. Vehicle emissions can be variable, especially for high emitting vehicles with intermittent emission control problems, even on carefully controlled Federal Test Procedure (FTP) certification tests in a laboratory. Because of emissions variability, some vehicles will fail an initial test, and pass a retest, without any effective repairs made. Similarly, some vehicles with a intermittent emission control problem will pass their initial test. Because these vehicles are only tested until they pass, they appear to be properly functioning, normal emitting vehicles.

The ideal I/M test would consistently measure vehicle emissions under several different driving conditions. The IM240 test is derived from the FTP, and measures mass emissions under a variety of speed and engine loads that simulate actual on-road driving conditions. However,

the cost of test equipment necessary for IM240 testing makes this procedure best suited for a small network (usually centralized) of high-volume test facilities. The California two-mode ASM test measures emission concentrations under two vehicle loads (5015, or 50% of the maximum load of the FTP at 15 miles per hour, and 2525, or 25% of the maximum load at 25 miles per hour). The two-speed idle test measures only HC and CO emissions when the vehicle is idling (curb idle test), and when it is in park or neutral gear and the engine is running at 2500 rpm (loaded idle test). Because NO_x emissions are extremely low at idle, the two-speed idle test does not measure on-road NO_x emissions.

The *Drive Clean* program currently uses the ASM2525 test mode, followed by a curb idle test, for light-duty vehicles (under 4500 kg test weight). The program uses the two-speed idle test for light-duty vehicles that cannot be tested on the ASM dynamometer. The ASM test is run until the vehicle's emissions stabilize for 10 seconds, and are lower than the applicable cutpoint for all three pollutants. All vehicles with high emissions are tested for 90 seconds; vehicles with emissions greater than the cut point, but less than 1.5 times the cut point, for any pollutant are given an immediate "second chance" retest. If emissions on the second chance test are lower than the cut points for all three pollutants, the vehicle passes. The emissions from the initial test and second chance test are stored in the same test record.

As with all I/M tests, vehicles that are not properly preconditioned (warmed up) prior to the test can be falsely failed. Most IM240 programs require that a vehicle be given two full IM240 tests before failing the test, as recommended by EPA in 1992. A study in Phoenix (which allowed vehicles to fast-fail the IM240 after as little as 90 seconds) found that 19% of vehicles that failed a single IM240 passed an immediate retest (Joy et al., 2004). In response to this study, Phoenix developed the IM147 test, which consists of up to three 147-second traces. A follow-up study found that a full IM147 test (total of 441 seconds) would more fully precondition a vehicle than back-to-back IM240 tests (480 seconds) in a shorter time, thus increasing vehicle throughput at test lanes.[22] A recent study of newer OBDII-equipped vehicles in Colorado found that some vehicles are not fully preconditioned even after two full IM240 tests (conversation with Rick Barrett, 5/18/05). Because inadequate preconditioning can lead to false failures, even on a transient loaded test such as the IM240 or IM147, it is likely that false failures are even higher on the shorter (90-seconds maximum), steady-state ASM test.

[22] ERG recently analyzed the number of false fails in the Phoenix IM147 program, by applying the contractor's fast-pass/-fail algorithm to a stratified random sample of vehicles given three full IM147 traces. 5% of the vehicles that would have been fast-failed passed the full IM147 test (and 18% of the vehicles that would have been fast-passed failed the full IM147 test).

Currently the *Drive Clean* preconditioning time is increased from 60 to 90 seconds in the winter, to ensure that vehicles are properly warmed up prior to testing in cold weather, in order to reduce the potential for false HC or CO failures. Conversely, the preconditioning time is decreased from 60 to 30 seconds in the summer, to ensure that vehicles are not overheated prior to testing, in order to reduce the potential for false NO_x failures. Evaporative HC emissions can fill up in the canister of a vehicle sitting in the sunshine on a hot day; the canister may purge these emissions at the start of the ASM test, resulting in fuel enrichment, which can cause a vehicle to falsely fail the ASM test. The DCO determines when the ASM preconditioning time should be adjusted; ProtectAir then remotely reprograms the OTU software to reflect the change in preconditioning time.

We examined the monthly trend in failure rates by pollutant, ambient temperature, and preconditioning time to assess the effect of temperature and preconditioning time on failure rates. Figure 5-10 shows failure rates, by pollutant and test type, for light-duty vehicles tested in the phase 1 area, by year and month. Only model years that were tested in each calendar year, 1985 to 1996, are included in the figure. The preconditioning period is noted by a heavy line in the figure. The figure indicates that tested in the summer (30-second preconditioning), the fall/spring (60-second preconditioning), and the winter (90-second preconditioning), at comparable temperatures, to assess what effect longer preconditioning times have on fail rates.

The figure indicates that, in general, ASM fail rates decreased from 1999 to 2000, were stable in 2001 and 2002, and increased in 2003 and 2004, especially for HC; the increase in the last two years is likely due to the lowering (tightening) of ASM cutpoints in January 2003. Figures 5-11 and 5-12 show comparable data for phase 2 and phase 3; Figure 5-13 shows the 2003-04 failure rates by month, as well as the maximum daily temperature from Toronto's Pearson International Airport.

Figure 5-10. Monthly Phase 1 Fail Rates, by Pollutant

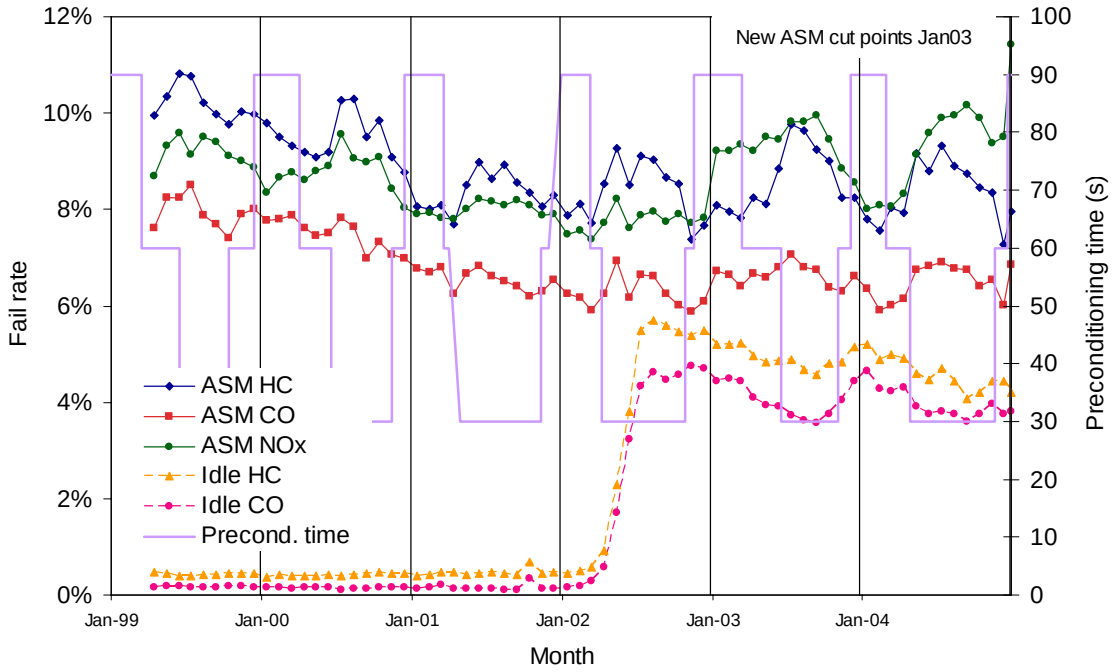


Figure 5-11. Monthly Phase 2 Fail Rates, by Pollutant

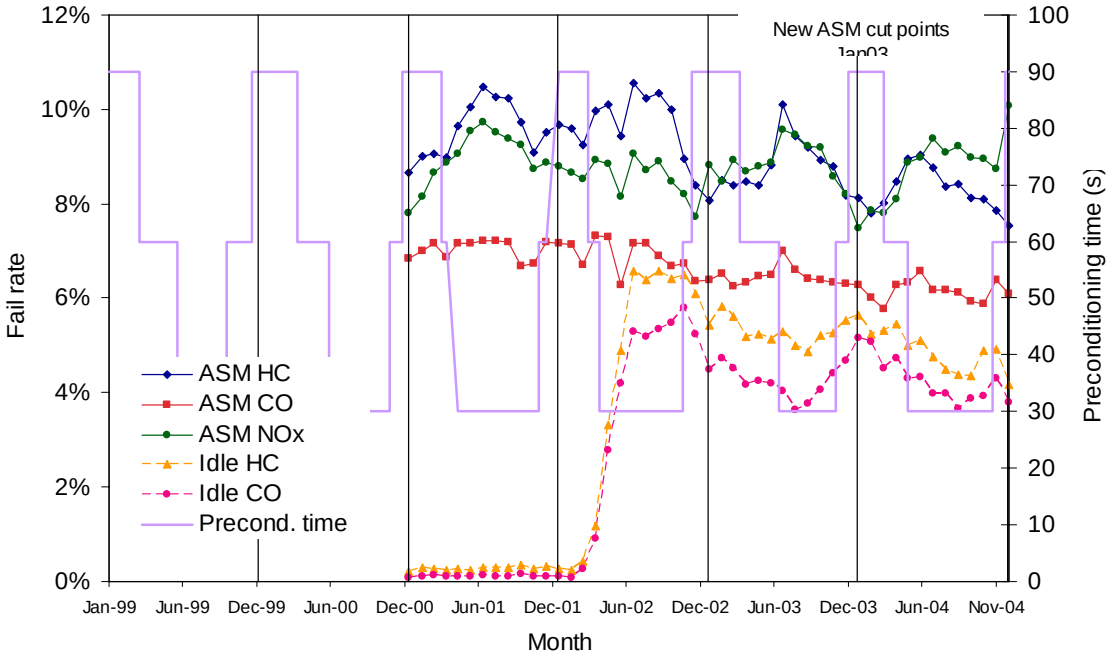


Figure 5-12. Monthly Phase 3 Fail Rates, by Pollutant

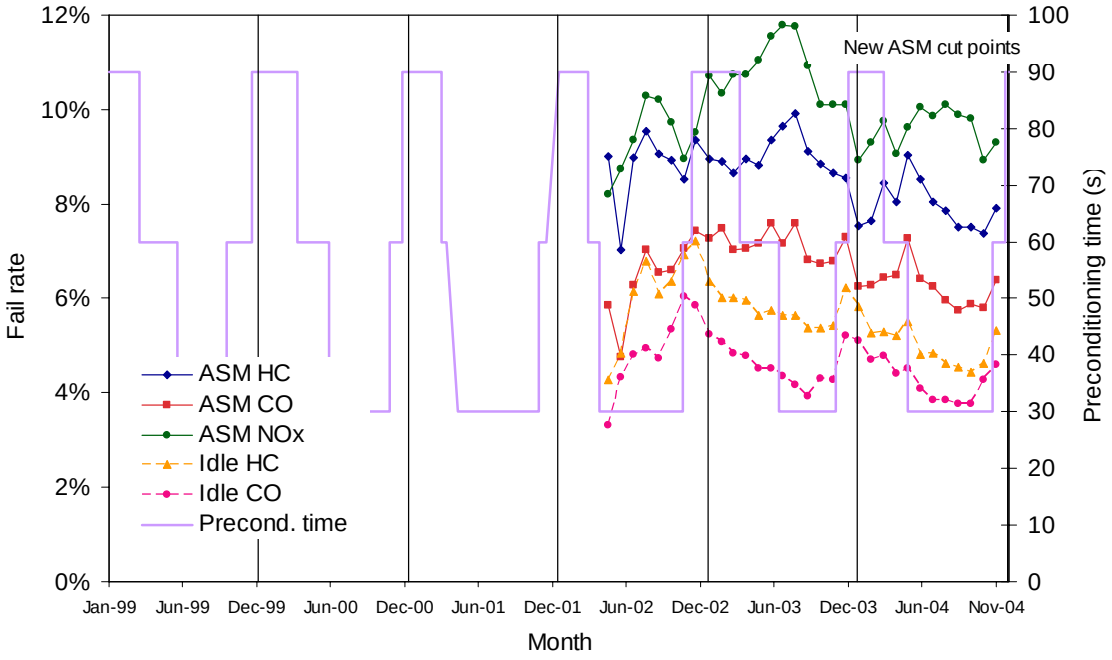
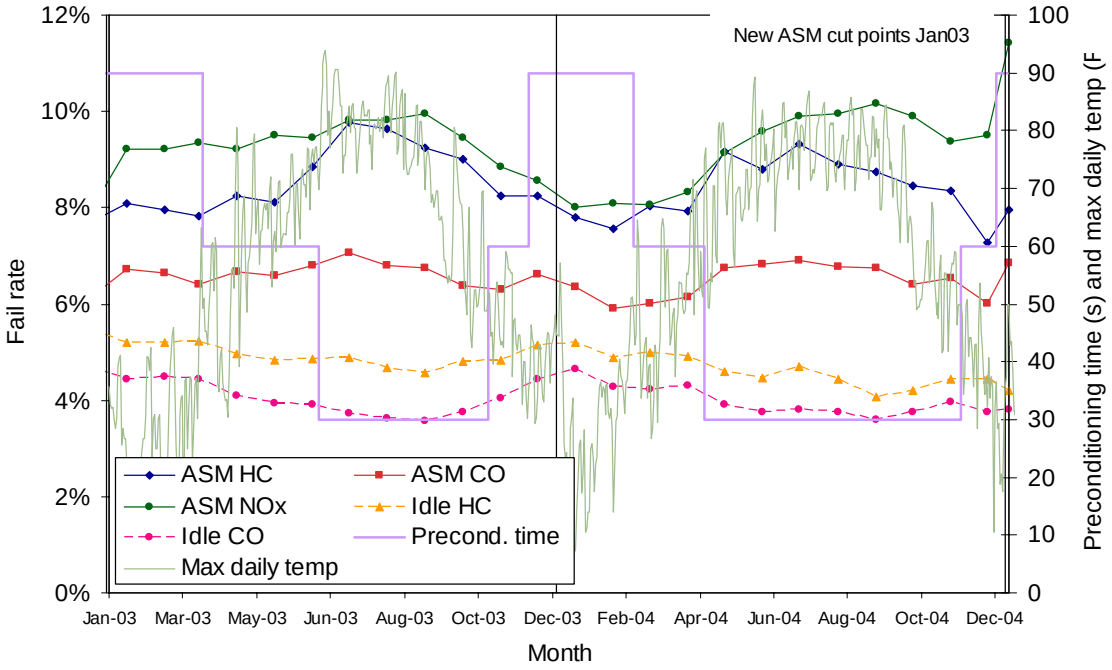


Figure 5-13. Monthly Phase 1 Fail Rates in 2003-04 by Pollutant, Preconditioning Time and Average Maximum Daily Temperature



The figures also indicate that ASM failure rates fluctuate throughout the year, with higher failure rates for all three pollutants in summer months and lower failure rates in winter months. Similar seasonal variation in failure rates has been observed in three centralized IM240 programs. In Arizona and Colorado, HC and CO failure rates are higher in summer and lower in winter, while NO_x failure rates are lower in summer and higher in winter. In Wisconsin, the seasonal variation is the opposite of that in Arizona and Colorado; HC and CO failure rates are higher in the winter, and NO_x failure rates are higher in the summer. It is believed that the seasonal fluctuation in failure rates is the result of a combination of inadequate vehicle preconditioning, seasonal changes in ambient temperature, and seasonal changes in fuel properties. As noted above, failure rates in Ontario are consistently higher in summer months for all three pollutants. The fluctuation in HC failure rates in Ontario appears to follow changes in the test preconditioning period and ambient temperature; the HC failure rate increases dramatically when the preconditioning time is reduced from 60 seconds to 30 seconds (from May to June), and continues to increase, perhaps as ambient temperature increases (from June to July). However, the HC failure rate then consistently decreases while the preconditioning time is held constant at 30 seconds, from July to October). The HC failure rate then decreases dramatically between October and November, a period when the preconditioning time is increased from 30 seconds to 60 seconds, and ambient temperatures are falling.

The curb idle failure rates in the figures show the opposite seasonal variation of the ASM failure rates, with lower failure rates in the summer and higher failure rates in the winter.

There is no discernible seasonal variation in failure rates in the California ASM program; however, there is less of a variation in ambient temperature, and preconditioning times are not adjusted by season, in California. It is not clear whether changes in ambient temperature, preconditioning times, changes in fuel properties, some other factors, or a combination of these factors are responsible for the seasonal fluctuation in failure rates in Ontario.

We then analyzed vehicles that received a second chance test in 2004. One-third of the vehicles that failed the ASM test had emissions less than 150% of the applicable cut point for each pollutant, and received a second ASM test. Of these, almost 60% also failed the second chance test. Of the vehicles that failed the second chance test, 14% had emissions for at least one pollutant over 1.5 times the cut point (the remaining 86% had emissions between 1 and 1.5 times the cut point for all pollutants).

If additional testing was causing a substantial increase in NO_x emissions due to engine overheating, one would expect that a large number of vehicles would have increased NO_x

emissions from the initial test to the second chance test (that is, would go from passing for NO_x to failing for NO_x, or would go from failing for NO_x to being a high NO_x emitter, from the initial test to the second chance test). For all vehicles that received a second chance test, only 1.9% had substantially higher HC emissions on the second chance test, while 4.1% had substantially higher CO and 5.2% had substantially higher NO_x emissions. Although a larger number of vehicles had substantially higher NO_x emissions on the second chance test than had substantially higher HC emissions, many vehicles also had substantially higher CO emissions on the second chance test.

Table 5-4 summarizes the results of vehicles that received a second chance test in 2004, by the overall result of the second chance test and the result of the initial test and second chance test for each of the three pollutants. The top panel of the table shows the results for vehicles that passed the second chance test overall (41% of all vehicles that received a second chance test). The middle panel of Table 5-4 shows the results of the vehicles that failed the second chance test with all emissions less than 1.5 times the cut points (50% of all vehicles that received a second chance test). The lower panel of Table 5-4 shows the results of vehicles that failed the second chance test with emissions of at least one pollutant more than 1.5 times the cut point (8% of all vehicles that received a second chance test).

Table 5-4. Initial and Second Chance Test Results for Vehicles that Received a Second Chance Test in 2004, by Pollutant

Result of overall second chance test	Initial test result for specific pollutant	Second chance test result for specific pollutant	HC	CO	NO_x
Passed second chance test (41%)	Fail <150%	Pass	69%	9%	31%
	Pass	Pass	31%	91%	69%
	All		100%	100%	100%
Failed second chance test with all emissions <150% of cut points (50%)	Fail <150%	Fail <150%	41%	15%	56%
		Pass	5%	2%	1%
	Pass	Fail <150%	0%	2%	1%
		Pass	54%	82%	42%
	All		100%	100%	100%
Failed second chance test with at least one emissions >150% cut point (8%)	Fail <150%	Fail <150%	11%	2%	4%
		Fail >150%	17%	28%	55%
		Pass	4%	1%	2%
	Pass	Fail <150%	2%	2%	2%
		Fail >150%	2%	7%	1%
		Pass	64%	59%	37%
	All		100%	100%	100%

The top panel indicates that, for vehicles that passed the second chance test, 69% had lower HC, 9% had lower CO, and 31% had lower NO_x, emissions on the second chance test. Therefore more passing vehicles had lower NO_x emissions on the second chance than had lower CO emissions on the second chance test. The middle panel indicates that, for vehicles that marginally failed the second chance test, none had substantially higher HC, 2% had substantially higher CO, and only 1% had substantially higher NO_x emissions on the second chance test. Again, the second chance test has a larger effect on CO emissions than NO_x emissions. However, the bottom panel shows that, for vehicles that failed the second chance test with high emissions, 17% of the vehicles had substantially higher HC, 28% had substantially higher CO, and 55% had substantially higher NO_x, emissions on the second chance test. Here, a larger number of vehicles went from marginal to high emissions for NO_x than for HC or CO.

The analysis above indicates that 5% of failing vehicles have substantially higher NO_x emissions on a second chance test; therefore, we would expect some vehicles would also have substantially higher NO_x emissions if they were preconditioned for a longer period. However, almost as many vehicles have substantially higher CO emissions on a second chance test.

A dataset of second-by-second emissions of a random sample of vehicles given a full ASM2525 test, followed either by another ASM2525 test or some additional drive cycle (such as the IM240), is necessary to estimate the percent of vehicles being falsely failed in the *Drive Clean* program because of inadequate preconditioning. Such a sample would allow an estimate of the fraction of *Drive Clean* fails that would pass if preconditioned for a longer period prior to testing. If such a test program were adopted, the sample could also be given a full IM240 test following the *Drive Clean* test; the resulting data could be used to establish correlations between ASM and IM240 testing, and provide mass emissions data on a larger sample of vehicles, to be used in estimation of the emission reductions from the program. Such a program would require the purchase and installation of IM240 test equipment, which the current program does not have, either at *Drive Clean*'s Vehicle Emissions Centre or an existing DCF.

5.1.2.5 OBDII Scan

All 1998 and later model year light-duty gasoline-powered vehicles sold in Canada are equipped with second-generation on-board diagnostics (OBDII). OBDII monitors powertrain (engine and transmission) components to detect any problems that may cause emissions to exceed allowable limits. OBDII can detect system malfunctions or deterioration, often well before the motorist becomes aware of any problem. When a problem that could cause a significant increase in emissions or could damage the vehicle is detected, or if a sensor is not

working properly, the OBDII system illuminates a dashboard warning light and stores the information in the vehicle's computer using standardized codes and information. This information about the system malfunction may then be retrieved by connecting a scan tool to a standardized diagnostic link connector (DLC) located inside the vehicle near the driver's seat. Scan tools may either be stand-alone handheld units, or may be integrated into another diagnostic system. Since all OBDII-equipped vehicles have this standardized DLC and all utilize common computer "languages" and system monitoring criteria, OBDII is suitable for use in a vehicle I/M program.

USEPA guidance recommends the OBDII test be used for pass/fail determination for 1996 and newer vehicles in US I/M programs. ERG evaluated the success of OBDII testing in US I/M programs in developing OBDII implementation options for the *Drive Clean* program. In 2004 57% of the entire registered light-duty fleet and 41% of the currently I/M-eligible fleet (i.e. 4-19 year old vehicles) in *Drive Clean* phase 1 was OBDII-equipped (model year 1998 and newer). Given the pervasiveness of OBDII systems throughout the fleet, and the potentially pervasive impact on *Drive Clean*, a detailed overview of the OBDII test issues considered by ERG in our assessment is presented below.

5.1.2.5.1 OBDII Fail Rates vs. Tailpipe Fail Rates

Although good agreement has been seen in overall pass rates between OBDII and tailpipe test results (the majority of vehicles pass both tests), many studies have shown less of a correlation among fail rates for each test type (vehicles fail one test but pass the other). Possible reasons for these conflicting results are widespread, including:

Study design: The way vehicles are selected can influence the results of the study. For example, selection of vehicles for an OBDII/tailpipe comparison study based on tailpipe emissions results alone will bias the results in favor of the tailpipe test. Additionally, uncertainty may result from studies conducted with a small number of vehicles.

Test type: The type of test and cutpoints used in an I/M program differ from those required for developing OBDII systems. In addition, OBDII systems are designed to identify system malfunctions or deterioration before tailpipe emissions increase. Two studies[23] [24] showed

[23] Gardetto, E.; Trimble, T. Evaluation of On Board Diagnostics for Use In Detecting Malfunctioning and High Emitting Vehicles; EPA-420-R-00-013, Office of Transportation and Air Quality, U.S. Environmental Protection Agency: August 2000.

[24] Durbin, T.; Norbeck, J. A comparison of Tailpipe Emission of On-Board Diagnostics Equipped Vehicles with the Malfunction Indicator Light Illuminated Before and After Repairs; Center for Environmental Research and

approximately 80% of vehicles with OBDII failures have tailpipe emissions less than 1.5 times the FTP certification standard for all pollutants. Although these types of failures are often miscategorized as "false failures", by design these may be appropriate OBDII failures, which, by identifying problems early, can minimize future repair costs and maintain low vehicle emission levels. Evaporative system failures, which wouldn't be detected in a tailpipe test, will also result in an OBDII failure. All these factors may cause a vehicle to fail one type of test while passing the other.

Test inaccuracies: Both vehicle-to-vehicle test variability (different responses of similar vehicles to identical tests) and test-to-test variability (variability in test procedures and tailpipe emission levels) affect the results obtained by tailpipe emissions testing. Also, tailpipe test pass rates have been shown to be sensitive to test conditions, such as ambient temperature, preconditioning, and testing method. Some studies[25] have shown that some vehicles that fail an I/M test subsequently pass a similar test under carefully controlled conditions in the laboratory). Although not as common, studies[12] [13] have also identified vehicles with OBDII failures that have no identifiable problem. Typically these tend to be intermittent problems such as misfires, which are real problems but not typically identified without OBDII or the use of an oscilloscope. Conversely, due to current OBDII monitoring requirements, some system malfunctions may result in significant emissions increases that are not identified by the vehicle's OBDII system, but which may be identified through a proper loaded test. However, OBDII technology (and regulation) is evolving to address these types of OBDII "false passes".

Although the number of high-emitting vehicles not identified by OBDII has been thought to be fairly low (one large study showed this to be approximately 10% [12]), some recent I/M program data from various states has shown indications that some vehicles found to have legitimately high tailpipe emissions may be passing OBDII inspections. This could in part be due to the "readiness exemption". Specifically, permitting an OBD vehicle with 2 "not ready" monitors may be allowing some vehicles with a malfunctioning component to pass the OBDII scan after an OBD system reset before that component is "ready". US EPA guidance recommends a maximum of 2 "not ready" monitors for model year 1996 – 2000 vehicles and a maximum of 1 "not ready" monitor for model year 2001 and newer vehicles. It is unlikely that many of these types of OBDII "false passes" will occur with only 1 "not ready" monitor allowed.

Technology at the University of California, Riverside article in the Journal of Air and Waste Management Association: September 2002.

[25] Barrett, R. Colorado's OBDII Study Update; presentation by the Colorado Department of Public Health and Environment; June 6, 2002.

5.1.2.5.2 Cost Effectiveness of OBDII Repairs

The cost effectiveness of OBDII-related repairs is an important factor when considering implementing an OBDII test program. Although one large US study indicated the cumulative emission reduction (benefit) of OBDII might be greater than that for tailpipe testing, this cumulative benefit was based on a higher OBDII than tailpipe fail rate, which would result in more money being spent on vehicle repairs (and therefore higher $ per ton costs). However, this doesn't account for the positive "preventative maintenance" benefit of OBDII, as described below. Other studies [26,27,28] have shown average repair costs to be about the same for OBDII and tailpipe testing. Conflicting results have been seen in studies comparing per-vehicle average and cumulative emissions reductions between OBDII and tailpipe testing. It is important to note that these studies are based on transient, mass-based emissions testing; results would likely vary if comparing fail rates and cost effectiveness of OBDII testing with those seen using ASM testing, adding significant uncertainty to our assessment.

Vehicle repair costs can usually be expected to increase if component malfunctions are left neglected. The fact that OBDII generally sets a trouble code before emissions significantly increase should be considered when evaluating the cost effectiveness of OBDII repairs. Addressing these system malfunctions in a timely manner helps prevent costlier future repairs (as well as helps maintain vehicle emissions at pre-failure levels).

5.1.2.5.3 Future Performance of OBDII

Since OBDII systems have been in use for a relatively short period of time, the performance of these systems in high-mileage and older vehicles is still somewhat uncertain. The USEPA has been conducting an ongoing study on the performance of OBDII systems in high-mileage vehicles. Thus far, this study has found that approximately 30% of vehicles with OBDII trouble codes had emissions below the threshold of 1.5 times the certification emissions standard. This is a much lower percentage than the 80% identified in an earlier study. This preliminary result suggests OBDII and tailpipe failures may have greater overlap as vehicles age (that is, OBD codes are less indicative of "preventative maintenance" needs, and more indicative of true emissions failures). Preliminary results of this high-mileage study also indicate emission reductions and average repair costs are comparable for these older vehicles.

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[26] Various spreadsheets developed by the Oregon Vehicle Inspection Program with analysis of BAR31/OBDII program data gathered between September 1999 and October 2000.

[27] Various spreadsheets developed by the Oregon Vehicle Inspection Program with analysis of BAR31/OBDII program data gathered between January 14, 2002 and January 19, 2002.

[28] Mobile Source Technical Review Subcommittee and the Clean Air Act Advisory Committee, Findings and Recommendations of the On-Board Diagnostics (OBD) Policy Workgroup, November 2002.

A recent analysis of two cycles of OBDII I/M testing in Phoenix found that the repeat failure rates of OBDII vehicles are similar to those of non-OBDII vehicles. 17% of vehicles that failed their initial OBDII test and passed a subsequent OBDII retest failed their next OBDII inspection roughly two years later; 18% of non-OBDII vehicles similarly failed a tailpipe test roughly two years after passing their previous test cycle. Although these results differ from analysis of *Drive Clean* data which shows nearly half the vehicles that fail their initial test in one test cycle also fail in the following test cycle, these results do suggest that OBDII vehicles are either as difficult to repair, or are subject to as high a degree of emissions variability, as non-OBDII vehicles.

However, other effects, such as aging, reparability, and repair durability, may not yet be fully understood. It is possible that these factors could have a significant impact on OBDII fail rates and the success of OBDII-related repairs in older vehicles, as well as overall cost-effectiveness.

The performance of OBDII systems in newer vehicles with very low emission certification standards is also unknown. Since the baseline emissions in these vehicles are so low, very slight incremental changes in emissions (as a percentage of the baseline emissions) could trigger an OBDII failure. Essentially OBDII is a "vehicle-specific" monitoring technology, which holds these ultra-clean vehicles to tighter test standards than older OBDII-equipped vehicles.

5.1.2.5.4 General Advantages and Disadvantages of OBDII vs. Tailpipe Testing

OBDII and tailpipe testing are each very different, and consequently each have their unique strengths and weaknesses. Some of these are listed below.

Key OBDII Strengths (relative to tailpipe testing)

- OBDII is designed to identify malfunctions before emissions increase - this helps keep emission levels low and prevents additional future repair costs.
- OBDII is designed to identify evaporative system malfunctions which cannot be identified in a traditional tailpipe test program
- Although OBDII is not entirely immune to test fraud, monitoring technology can generally detect emission control component tampering before such tampering results in emissions increases. For example, an OBDII system will detect if an EGR, oxygen sensor, or catalytic converter are removed from a vehicle. OBDII technology also offers additional information which may be used to identify test fraud through record review, such as comparison of OBDII communication

protocols, powertrain control module (PCM) identification numbers, and parameter identification (PID) counts with "master tables" of known values for vehicle types. Comparing these values for the same vehicle subject to a retest can also offer clues into possible test fraud.

- OBDII-only inspections are quicker and easier to conduct with less expensive equipment than tailpipe testing
- OBDII generally provides more specific fault diagnosis information than tailpipe testing
- OBDII generally allows higher confidence that the underlying cause of test failure has been corrected
- Due to the relatively low cost and ease in performing inspections, some I/M programs have elected to expand into new regions as OBDII-testing only. In so doing, the programs have been able to include an appreciable portion of the fleet with minimal expenditure.

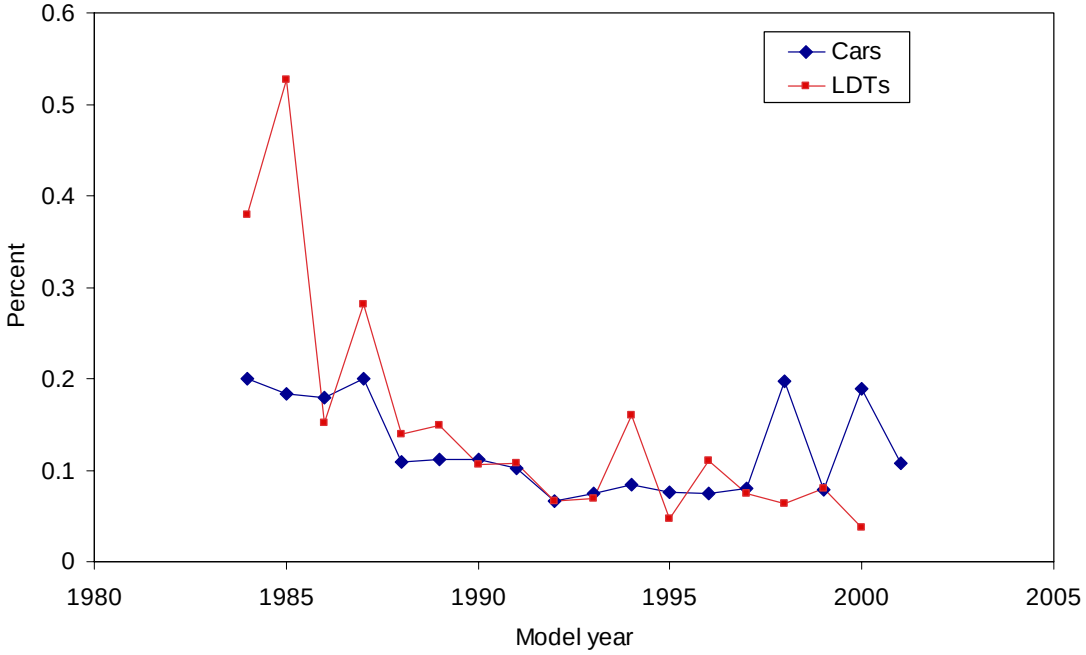
Key OBDII Weaknesses (relative to tailpipe testing)

- OBDII does not allow direct measurement of tailpipe emissions, and therefore the true emission reduction benefit of the I/M program cannot be determined using the OBDII test results alone. Emission reductions attributable to an OBDII-only program would need to be determined using some type of supplemental testing or modeling.
- Performance of OBDII systems on high-mileage vehicles is still somewhat uncertain.
- Performance of OBDII systems on aging vehicles, especially those subjected to harsh environments or driving conditions, is still somewhat uncertain.
- Performance of OBDII systems on newer ultra-low emission vehicles is uncertain.

5.1.2.6 Idle Test

About 10% of all fail-pass light-duty vehicles passed the ASM test but failed the curb idle test. Figure 5-14 shows that this occurred fairly consistently for all model years, for both cars and trucks. It appears that adding the curb idle test to the ASM test results in additional emission reductions, at least for HC and CO; however, these reductions are small (SBA report estimates 5% of total HC and CO, and 3% of total NO_x, emission reductions in phase 1 in 2003 came from repairs to idle-only failures). Appendix A shows the initial and final ASM emissions of vehicles that passed the ASM test but failed the idle test, by model year.

Figure 5-14. Percent of all 2003-04 Fail-Pass Vehicles that Failed the Idle Test only, by Model Year and Vehicle Type



5.1.2.7 Test Fees

Drive Clean fees were originally capped at CDN$30 per initial test, and CDN$15 per retest, for light-duty vehicles. The fees were increased to CDN$35 per initial test and CDN$17.50 per retest in October 2002. DCO receives one-third of the fee for each passing initial test (CDN$11.67), and two-thirds of the fee for each passing retest (CDN$11.67); the DCFs receive the balance of the fee paid for passing tests, as well as all of the fee paid for failing tests.

Comparison of test fees across I/M programs is not straightforward, as some programs (such as *Drive Clean*) are funded entirely by a portion of the test fee, whereas others are funded by a portion of vehicle registration fees or other revenue; consequently, some programs do not charge a fee for I/M tests. Test fees range from zero (in Delaware, Illinois, Indiana, and New Jersey) to CDN$59 (US$47, in Rhode Island). 7 jurisdictions have the same or higher test fee than *Drive Clean* (Arizona CDN$35, District of Columbia CDN$38, Massachusetts CDN$37, Nevada CDN$44, Rhode Island CDN$59, Texas CDN$50, and Virginia CDN$35), while 22 jurisdictions have a lower test fee. The test fee is determined by the market in 6 jurisdictions (Alaska, California, New Mexico, North Carolina, Pennsylvania, and Utah); Alaska requires that stations can charge a maximum test fee of CDN$63 (US$50), while the average fee in California is CDN$62 (US$49).

5.1.2.8 Cutpoints

From 1975 through 1987 vehicle manufacturers were allowed to build vehicles for sale in Canada that were certified to the 1975 US emission standards. However, vehicle manufacturers only developed Canadian versions of high sales volume vehicles (due to the additional vehicle development costs). As a result, the Canadian vehicle fleet from this time period consists of cars and trucks certified to the 1975 US emission standards (so-called Canadian calibrations), and US calibrations that were common to the vehicles sold in the US. The US vehicles were certified to tighter emission standards. The current Ontario Test Unit software can only assign emission cutpoints based on model year, vehicle type and weight, so the cutpoints had to be relaxed for pre-1988 vehicles to allow for the Canadian calibration vehicles. More recently, the US adopted Tier 1 (and OBD-II standards through a phased in approach for 1994 through 1996 model years. Canada delayed implementation of OBD II until the 1998 model year.

The cut points used in I/M programs are not necessarily related to the new vehicle emission certification standards. Because older model years have higher emissions than newer model years, I/M cutpoints tend to be looser (higher) for older model years, and more stringent (lower) for newer model years. Because LDTs generally meet less stringent certification standards than cars when new, I/M cutpoints tend to be looser for LDTs than for cars. Cutpoints are set in such a way to maximize the emission reduction potential of vehicles that are failed. If cutpoints are set too high, too few vehicles will fail; if they are set too low, too many vehicles will fail, and it may be difficult for some failing vehicles to be repaired to meet the cutpoints. These vehicles may either be permanently removed from the I/M program area (resulting in a benefit to air quality), or may receive an emissions test waiver, find a way to renew their registration without completing program requirements, or continue to be driven unregistered.

EPA developed recommended phase-in and final cutpoints for the two-mode ASM test (an ASM5015 followed by an ASM2525); most ASM programs use EPA's cutpoints. California has developed their own cutpoints for the two-mode ASM test, which tend to be more stringent than the EPA final cutpoints. California has tightened their cutpoints several times since they started ASM testing in mid-1998; California has not estimated the fraction of vehicles that are falsely-failed or –passed using these cutpoints. California also has higher gross polluter cutpoints; vehicles with extremely high emissions that fail these cut pints are required to pass a retest at a centralized test-only facility.

The *Drive Clean* ASM emissions cutpoints used to determine whether vehicles pass or fail emissions testing vary by vehicle test weight and model year (age); the idle cutpoints for

four-wheel drive light-duty and heavy-duty non-diesel vehicles, as well as the opacity cutpoints for heavy-duty diesel vehicles, vary by model year. Large changes in fail rates by model year or pollutant may indicate cutpoints that are either too stringent or too lax relative to cutpoints for other model years or pollutants.

Cutpoint Comparison By Model Year

Figure 5-15 and 5-16 show the average ASM cutpoints by pollutant, model year, and test year, for cars and light trucks. The cutpoints for 1988 cars are much tighter (lower) than those for 1987 cars; in addition, the NO_x cutpoints for 1992 cars are much tighter than those for 1991 cars. There are similar tightening of the cutpoints for model year 1984, 1988, and 1992 light trucks, and of the NO_x cutpoints for 1996 trucks.

Figures 5-17 and 5-18 show the fail rates by test type (ASM and idle) and pollutant (HC, CO and NO_x), for cars and light trucks. In general, the fail rates decline with increasing model year (or decreasing vehicle age); however, there are several peaks in the distributions of fail rates that correspond to the tightening of cutpoints for specific model years (as seen in Figures 22 and 23). For instance, the HC fail rate increases for 1988 cars, while the car NO_x fail rate increases for 1992 cars. Similarly the ASM fail rates for all three pollutants increase for 1992 LDTs. All of these sharp deviations in the curves of fail rates by model year correspond to large changes in the cutpoints for those particular model years. Interestingly, the CO and NO_x fail rates for 1988 cars do not appear to be effected by the large reductions in the CO and NO_x cutpoints for 1988 cars.

Figure 5-15. Average Cutpoints for Cars, by Pollutant, Year and Model Year

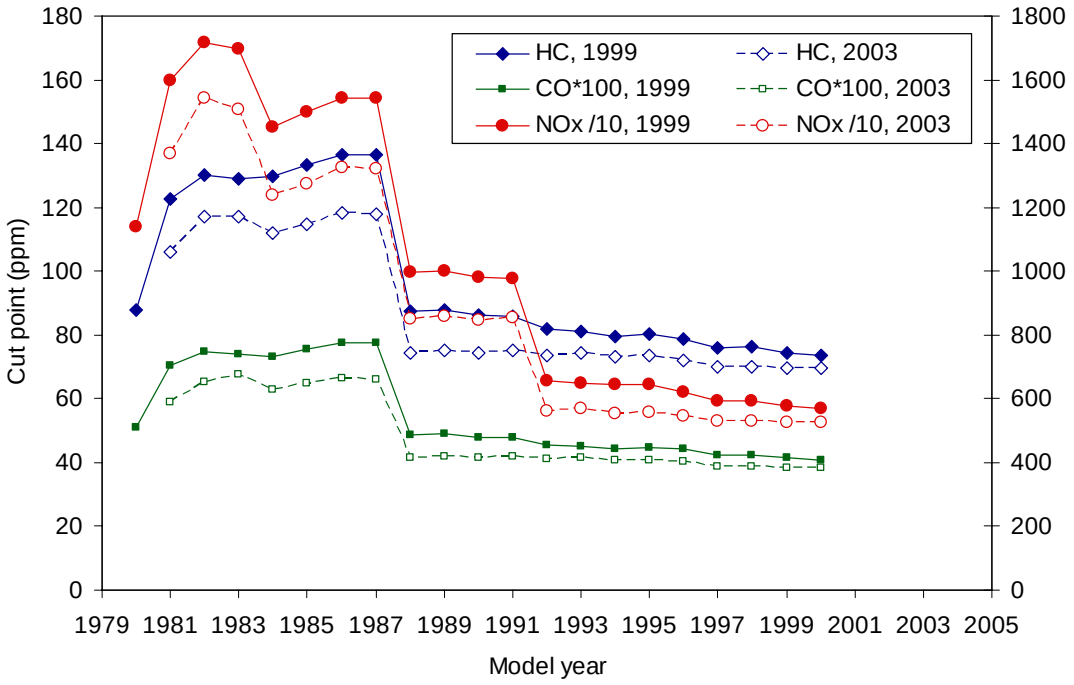


Figure 5-16. Average Cutpoints for LDTs, by Pollutant, Year and Model Year

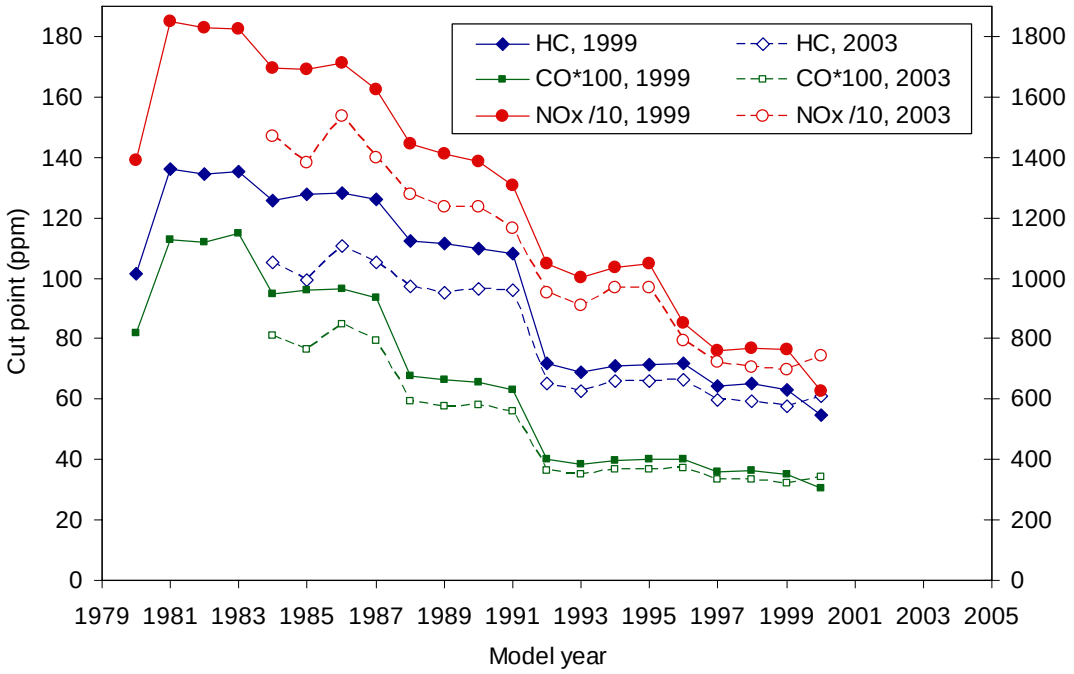


Figure 5-17. 2003-04 Car Fail Rates by Pollutant and Model Year

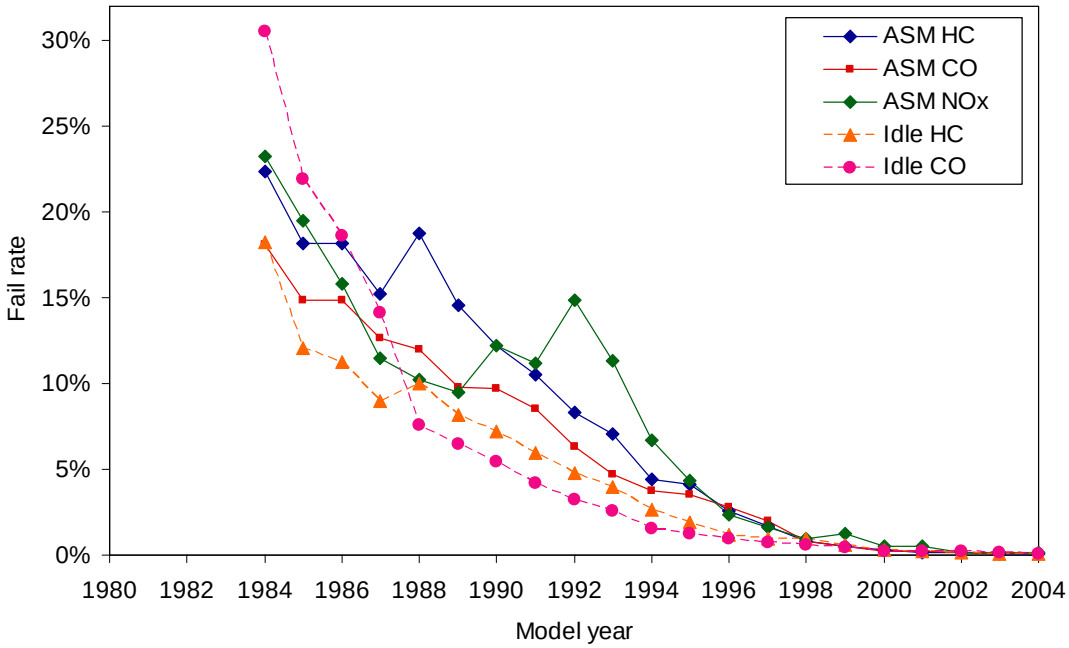
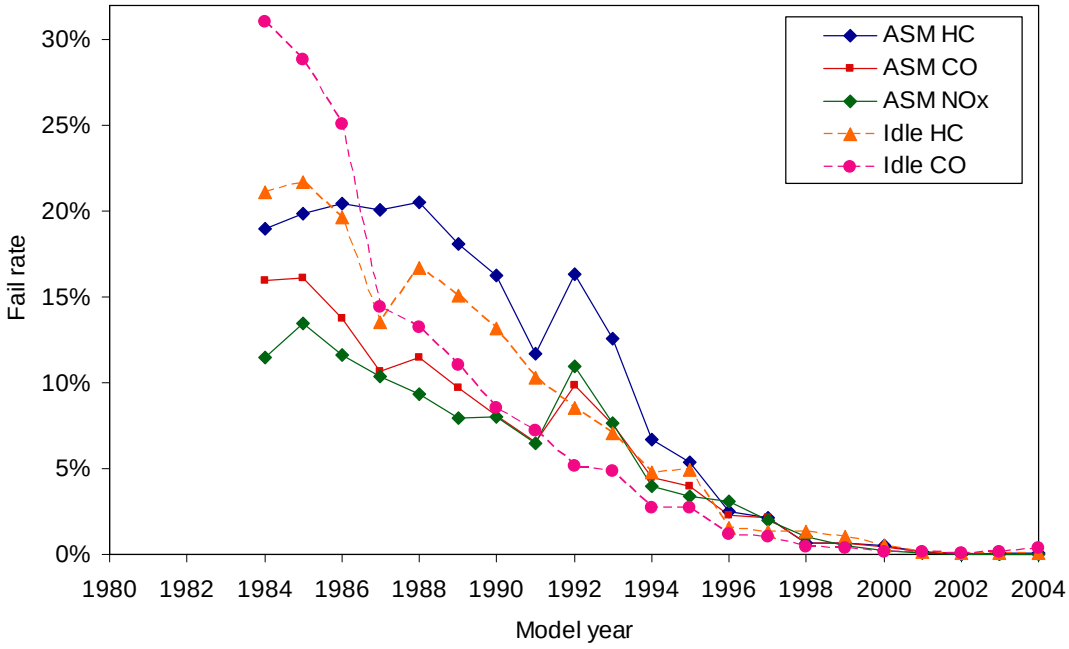


Figure 5-18. 2003-04 LDT Fail Rates by Pollutant and Model Year



Failure Rate by Pollutant and Test Mode

Figures 5-19 and 5-20 show the ratio of fail rates by test type and pollutant to the idle CO fail rate, by model year, for cars and light trucks. Figure 5-26 indicates that car fail rates for all three pollutants are comparable for model years 1984 to 1987 and model years 1996 to 1998; however, more cars in the 1988 and 1989 model years, and more fail for NO_x in the 1992 through 1994 and 1999 and newer model years. For light trucks, CO and NO_x fail rates are comparable, while HC fail rates tend to be higher, for 1995 and older model years, as shown in Figure 5-27.

Effects of Cutpoint Changes

The ASM cutpoints for light-duty vehicles have been tightened (lowered) in the program area twice, in January 2003 and January 2005. Figures 5-21 and 5-22 show the effect of the 2003 changes in cutpoints on overall failure rates in phase 1 by model year, for cars and light trucks. During this period the fail rates increased for 1989 and newer model years; however, not all of the increase was due to the tighter cutpoints, as one would expect the failure rate to increase over time as a particular model year ages.

Figures 5-23 and 5-24 show the changes in phase 1 failure rates before and after the 2003 changes in cutpoints, by pollutant and model year, for cars and light trucks. The *Drive Clean* cutpoints were lowered another 11.5% in January 2005.

Cutpoint Comparison with Other Jurisdictions

It is difficult to compare ASM cut points across I/M programs, as they typically are a function of vehicle type, age, and test weight. *Drive Clean* Figures 5-25 and 5-26 compare the California ASM2525 Phase 4.3 cutpoints (effective January 2003) with the *Drive Clean* cutpoints in effect in January 2005, by pollutant, vehicle type and model year. For cars, the *Drive Clean* cutpoints are more stringent (lower) than the California cutpoints, for HC for 1988 to 1992 cars, for CO for all model years, and for NO_x for 1992 and newer cars; the *Drive Clean* cutpoints are less stringent (higher) than the California cutpoints only for HC for 1993 and newer cars, and for NO_x for 1987 and older cars.

For LDTs, the *Drive Clean* cutpoints are more stringent than the California cutpoints for HC for 1992 and older LDTs, for NO_x for 1996 and newer LDTs, and much more stringent for CO for all model years. The *Drive Clean* LDT cutpoints are slightly less stringent only for NO_x for 1991 and older LDTs.

Figure 5-19. Ratio of 2003-04 Car Fail Rates to Idle CO Fail Rate, by Pollutant and Model Year

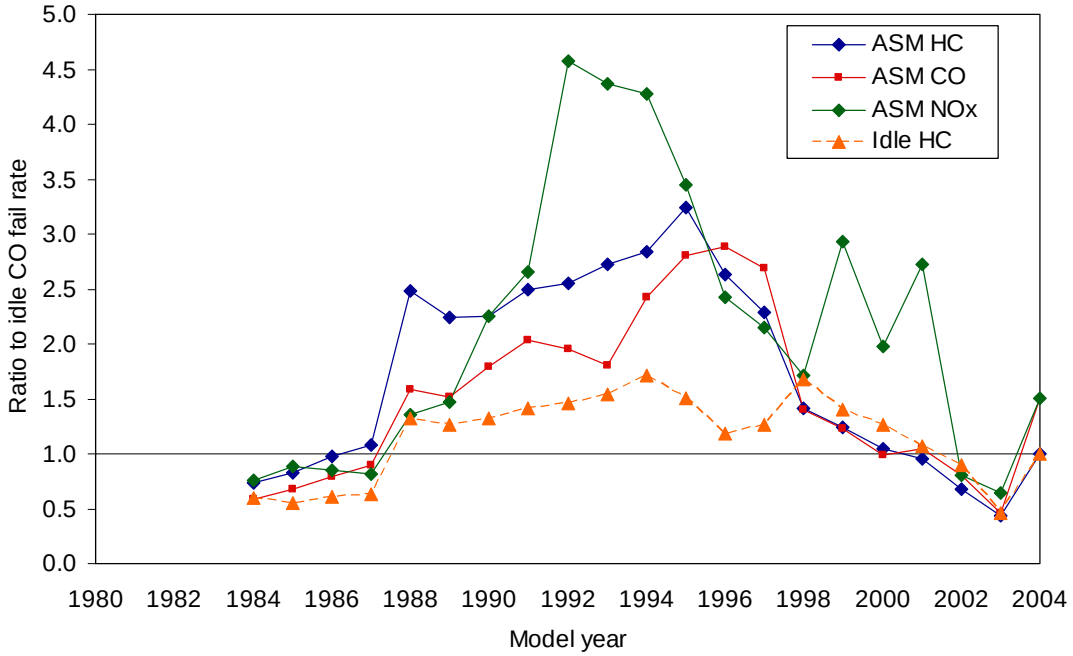


Figure 5-20. Ratio of 2003-04 LDT Fail Rates to Idle CO Fail Rate, by Pollutant and Model Year

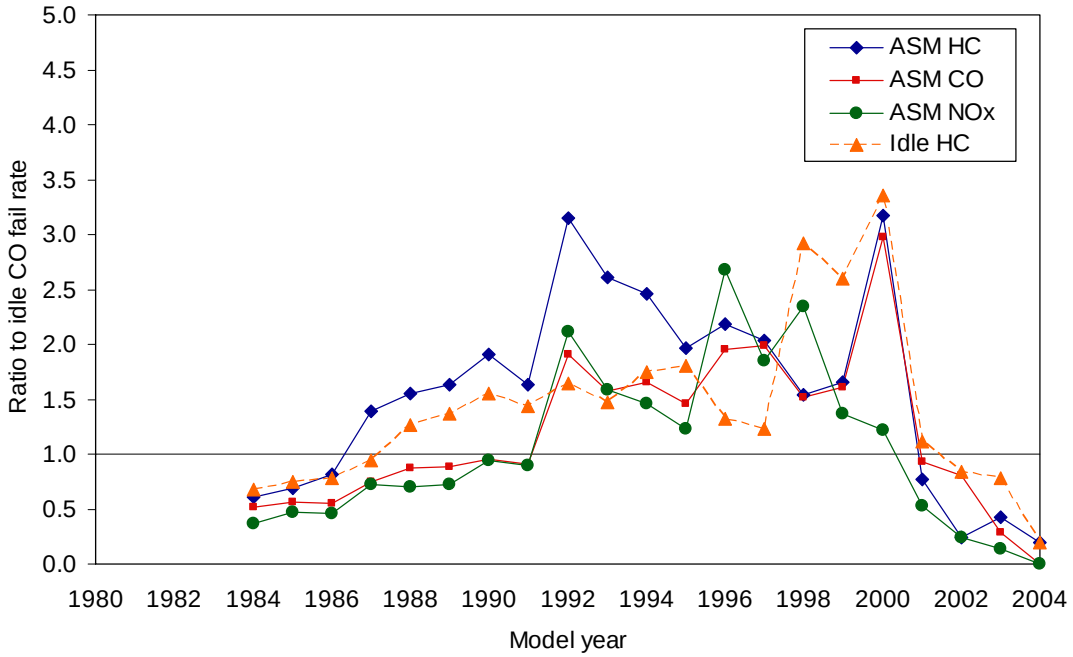


Figure 5-21. Car Fail Rates, by Year and Model Year

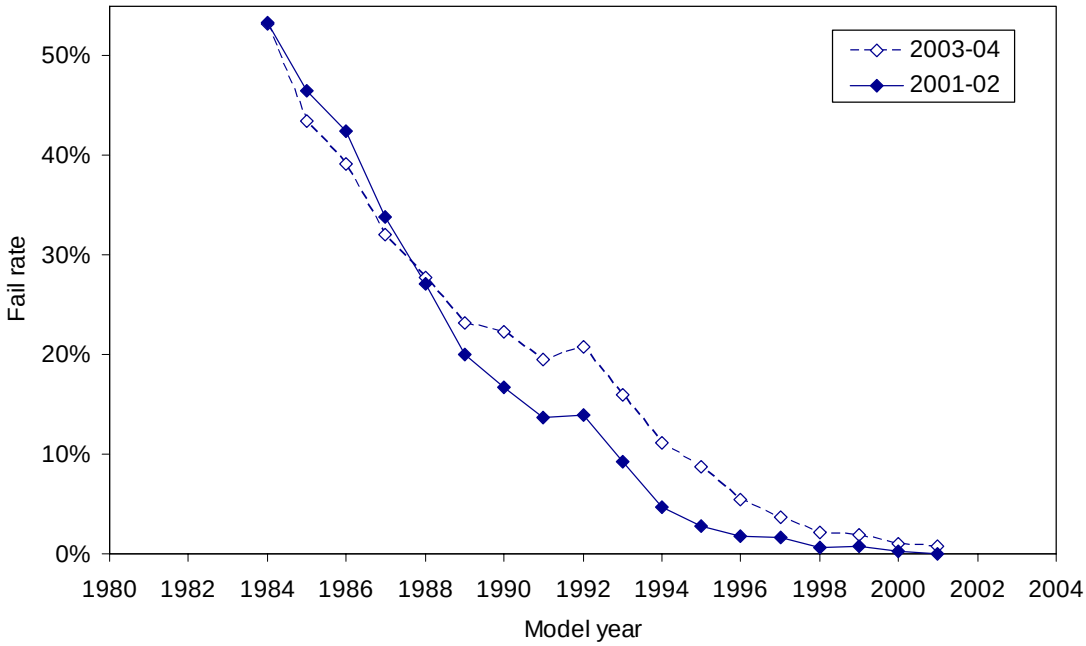


Figure 5-22. LDT Fail Rates, by Year and Model Year

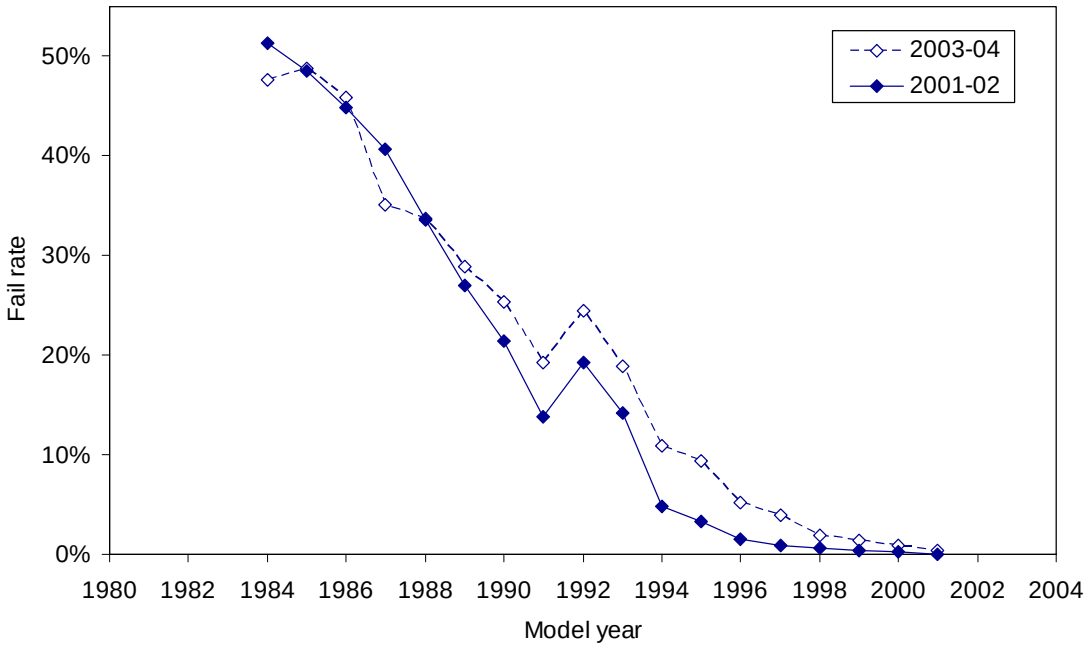


Figure 5-23. Car Fail Rates, by Pollutant, Year and Model Year

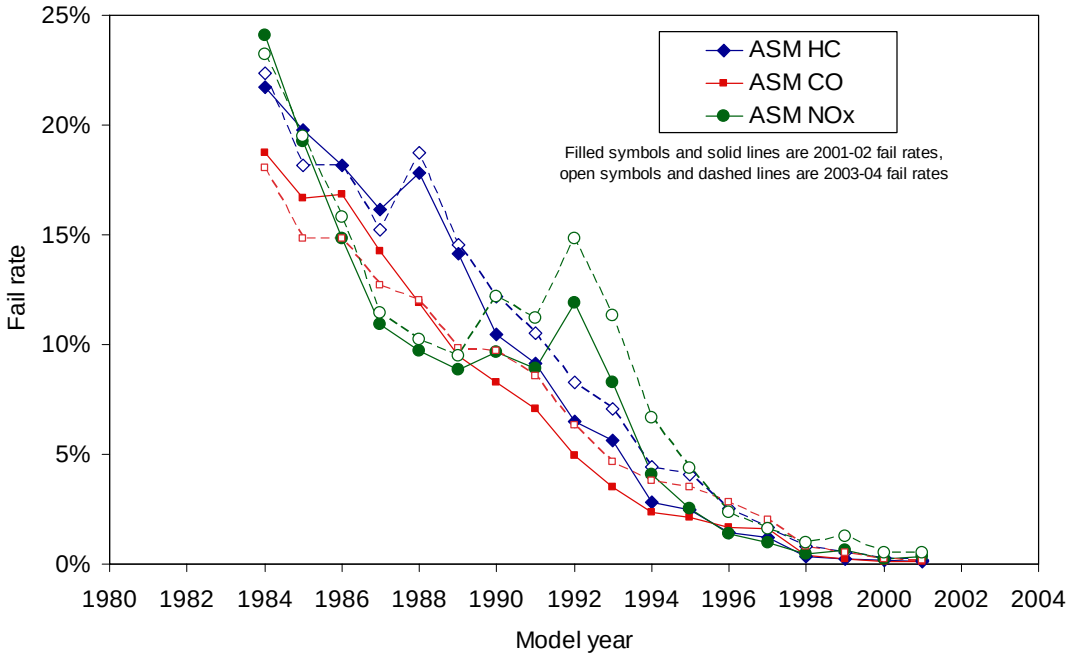


Figure 5-24. LDT Fail Rates, by Pollutant, Year and Model Year

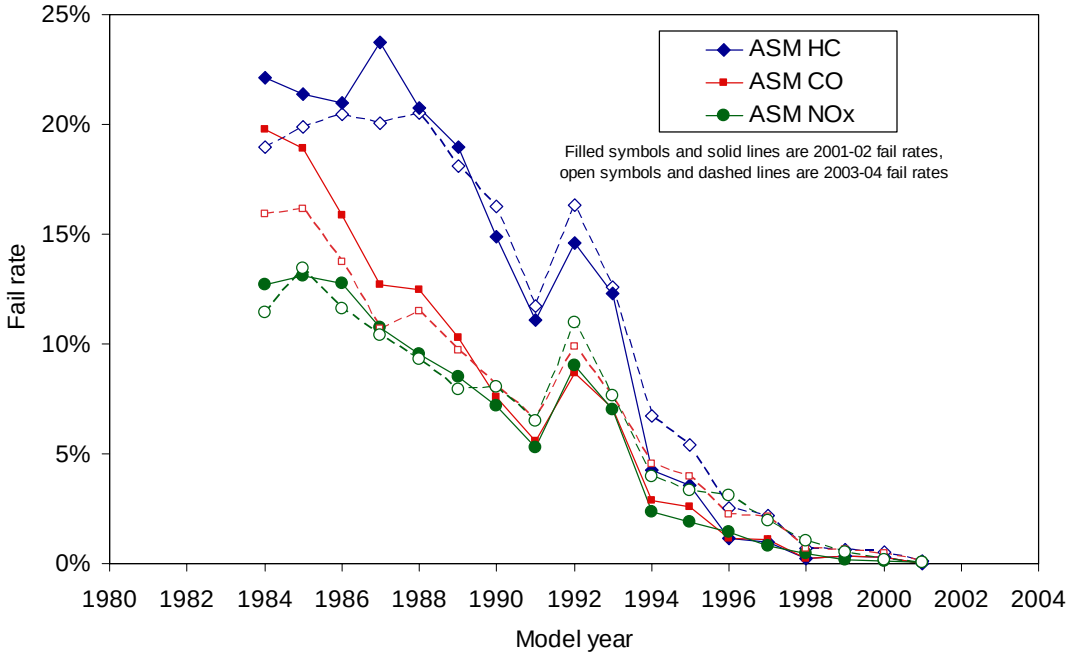


Figure 5-25. Average Cutpoints for Cars, by Program, Pollutant and Model Year

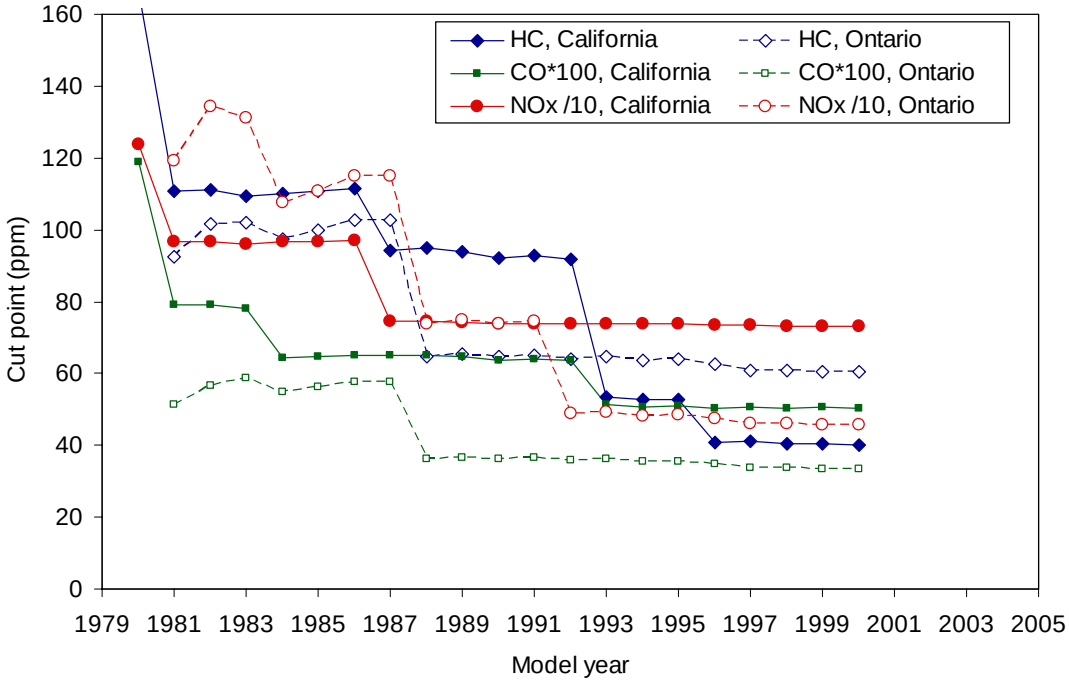
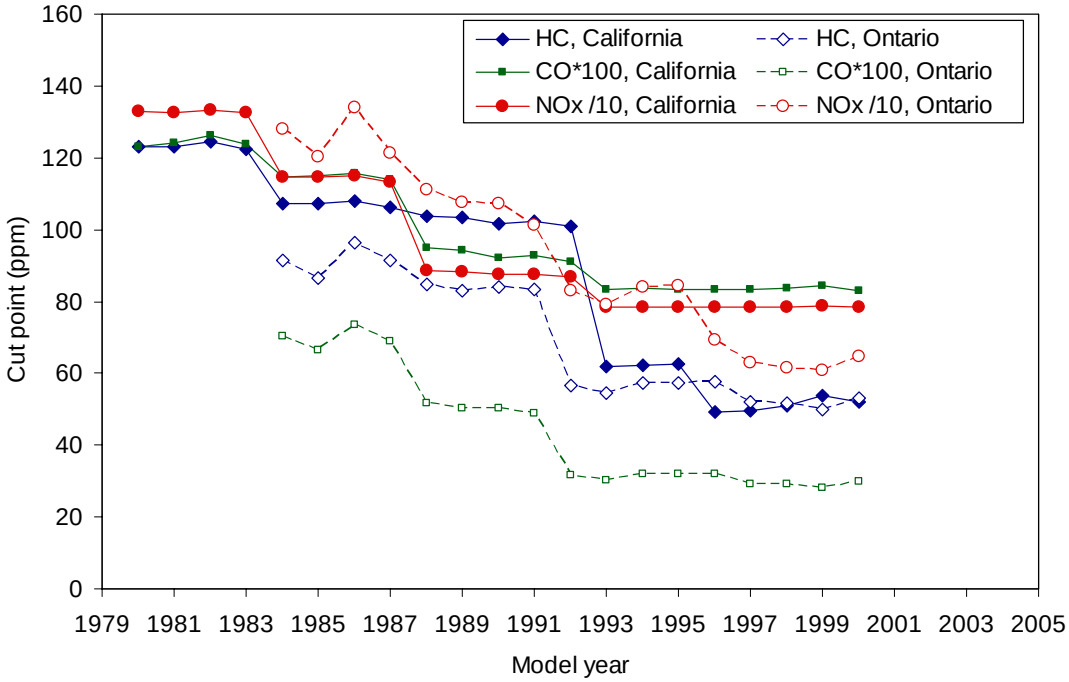


Figure 5-26. Average Cutpoints for LDTs, by Program, Pollutant and Model Year



Tightening the cut points further would increase failure rates, and potentially increase emission reductions, in the program. However, since the cut points were just tightened in January 2005, they should not be changed until at least January 2007.

Table 5-5 shows the cutpoints used for the two-speed idle test given to light-duty gasoline vehicles that cannot be tested on the ASM dynamometer (usually because they are four- or all-wheel drive).

Table 5-5. Two-Speed Idle Cutpoints for Light-Duty Gasoline Vehicles that Cannot be Tested on a Dynamometer

Weight	Model year	HC (ppm)	CO (%)	Visible smoke (seconds/minute)
<=3855 kg GVWR	1980 and older	600	5.0	5
	1981-87	300	1.5	5
	1988-97	200	1.0	5
	1998 and newer	150	0.7	5
3856-4500 kg GVWR	1969 and older	1000	8.0	5
	1970-74	800	6.5	5
	1975-79	400	4.0	5
	1980-87	300	3.0	5
	1988-97	220	1.2	5
	1998 and newer	200	1.0	5

[1] The same cutpoints are used for both the curb idle and loaded idle (2500 RPM) mode

5.2 Repair Issues

5.2.1 Repair Effectiveness

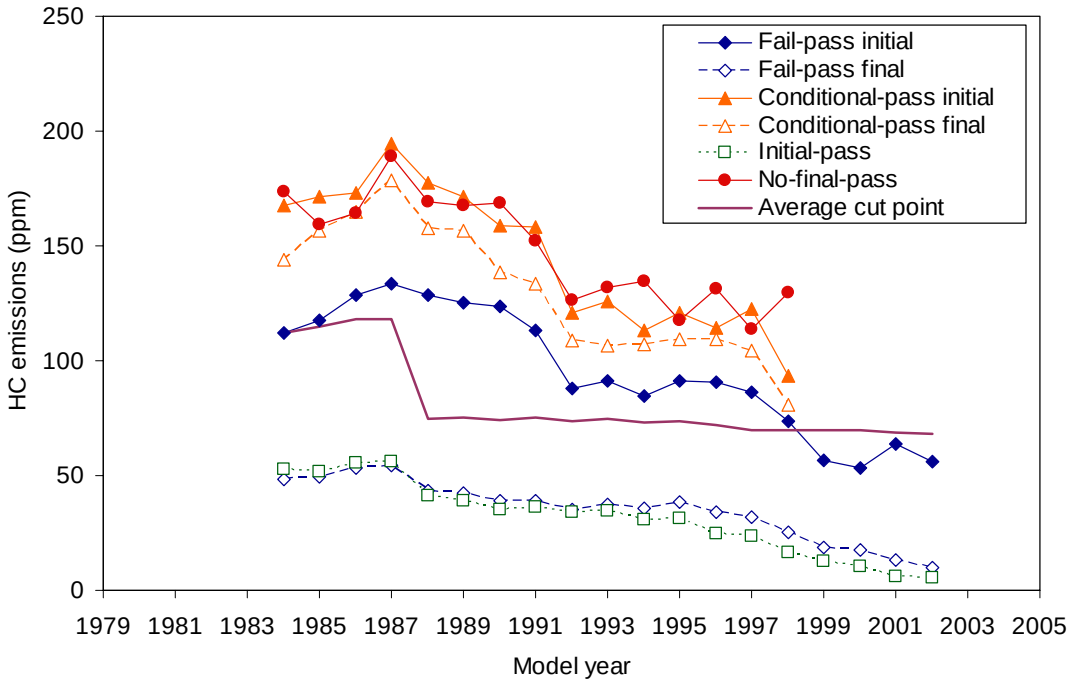
Proper identification of vehicles with high emissions is an important aspect of an I/M program. However, emission reductions are only obtained if the identified high emitters are repaired to actually lower emissions, and if those repairs are durable. All I/M programs have struggled with ensuring that effective and durable repairs are performed on failed vehicles.

Emissions Comparison By Previous Test History

Repair effectiveness can be measured by comparing emissions from the final passed retest with those from the initial failed test, for fail-pass and conditional-pass vehicles. However, this is only the initial effectiveness from repairs; emissions can increase (deteriorate) soon after the passed retest. In our discussion, repair effectiveness refers to repairs that result in an immediate emission reduction (to appropriate emission levels for the vehicle) that are also durable (emissions remain low).

Figure 5-27 shows the average HC emissions on the initial and final test in each I/M cycle, for cars, by I/M cycle result (fail-pass, conditional-pass, initial-pass, and no-final-pass). Trends for CO and NO_x are similar, and are included in Appendix A.

Figure 5-27. 2003-04 Car HC Emissions, by Test Result and Model Year

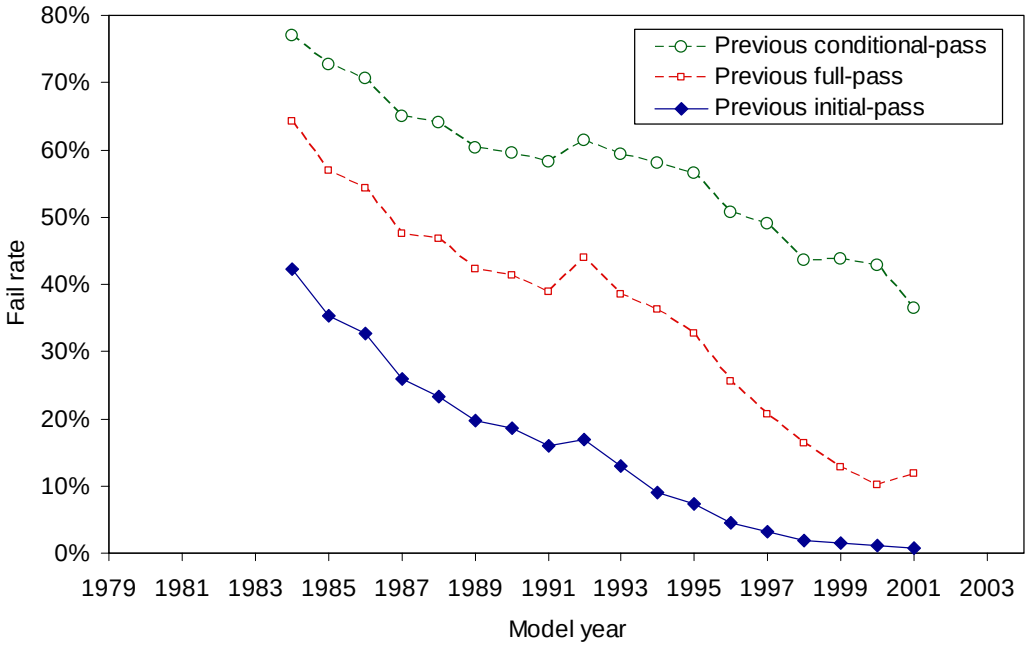


Failure Rate Comparison By Previous Test History

A more accurate measure of repair effectiveness (in particular durability) is the failure rate on the next I/M test following a passing test. Figure 5-28 shows the 2003-04 failure rate for light-duty vehicles in phase 1, by model year and the result of the previous test cycle. While the vehicles that initially passed their previous cycle had a failure rate of 9%, fail-pass vehicles in the previous cycle had a 41% failure rate, while conditional-pass vehicles in the previous cycle had a 62% failure rate. Figure 5-28 indicates that the failure rate decreases with increasing model year (decreasing age); the repeat failure rate of previous fail-pass vehicles ranges from 64% for 1984 vehicles to 12% for 2001 vehicles, while the repeat fail rate of previous conditional-pass vehicles by model year ranges from 77% to 36%. The repeat failure rates for fail-pass vehicles in their previous cycle are comparable to those seen in U.S. centralized I/M programs (Arizona and Colorado). This data suggests that repairs performed for initially failing vehicles may not be durable, both for older and newer vehicles (as shown by the parallel slopes of the lines in Figure 5-28). Although older vehicles that initially fail have a greater chance of

failing their initial test during the next cycle than newer vehicles, this trend may be due as much to older vehicles having an overall higher fail rate than newer vehicles.

Figure 5-28. 2003-04 Fail Rates, by Result from Previous Cycle and Model Year



Because conditional-pass vehicles receive, at best, only partial repairs, we expect that their emissions will deteriorate faster between I/M tests, and they will exhibit higher repeat fail rates, than fail-pass vehicles. One might expect that the failure rate for the previous conditional-pass vehicles would be closer to 100%, as these vehicles not only failed their initial test but failed a retest as well. However, this trend is not seen. In fact, initial test emissions for vehicles that were previously issued a conditional pass are generally lower than the prior cycle's retest emissions (before the conditional pass was issued).

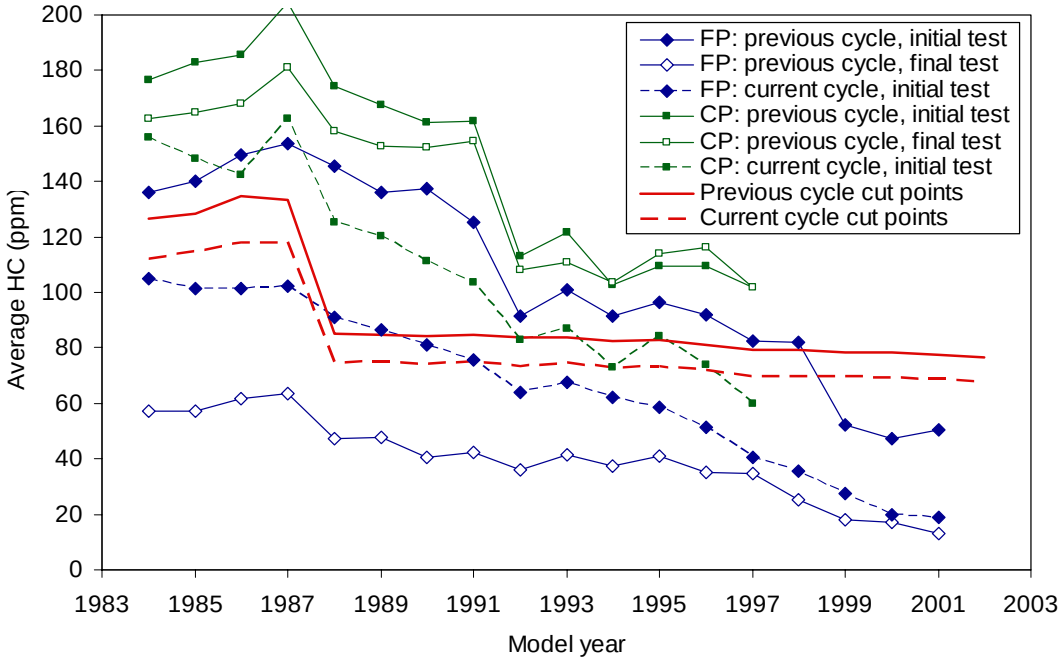
Current Cycle Emissions By Previous Test Result and Model Year

Figure 5-29 compares the initial and final HC emission levels of cars in the previous cycle with their initial emissions in the current cycle, by previous I/M result and model year. The figure shows that, for previous fail-pass vehicles (blue diamonds), the final (passing) emissions in the previous cycle are well below the cutpoints, while the initial emissions in the current cycle are about midway between the initial and final emissions in the previous cycle.

Again, as about 42% of the fail-pass vehicles fail again, this initial test average is made up of 42% of vehicles whose emissions would be closer to the previous fail-pass emissions (hollow blue diamonds) and the remaining vehicles (58%) would be close to the previous cycle final test. Also, older model year vehicles have a higher fail-pass-fail percentage and an associated higher emissions level.

By contrast, for conditional-pass vehicles (green squares), the final emissions are slightly lower than the initial emissions for the previous cycle, but both are well above the cutpoints. However, the initial emissions in the current cycle are well below the final emissions in the previous cycle, although still, for the most part, higher than the cutpoints. The trends for CO and NO_x are similar to those in Figure 5-29, and are included in Appendix A.

Figure 5-29. Average 2003-04 Car HC Emissions in Current and Previous Test Cycle, by Previous Test Result and Model Year



Note that the average emissions of the previous conditional-pass vehicles on the initial test in the current cycle are, for most model years, higher than the cutpoints, yet the overall failure rate of these vehicles in the current cycle ranges from 77% to 36% by model year.

5.2.2 Repair Cost Limits

The *Drive Clean* program allows failing vehicles to receive a conditional-pass (referred to as a repair cost waiver in other jurisdictions) if actual or estimated repairs cost in excess of a repair cost limit of CDN$450 (US$357). EPA recommended a repair cost limit of US$450 (CDN$567) in 1992 for enhanced IM240 programs; currently 21 jurisdictions, including British Columbia, have a repair cost limit of US$450 (CDN$567) or higher.

The *Drive Clean* repair cost limit is somewhat unique to those used in other programs, in that more than one conditional-pass can be issued for a particular vehicle in its lifetime, and the full repair cost limit does not have to be spent in order to qualify for the conditional-pass (i.e. a vehicle can qualify if the next recommended repair would bring the cumulative repair costs for that vehicle above the limit). *Drive Clean* and the British Columbia AirCare program have much higher conditional-pass rates, as a percent of initial fails, than U.S. I/M programs (10% to 15%, compared with less than 2%). In the *Drive Clean* program, conditional-passes are granted when repairs are made at a *Drive Clean* accredited repair facility. If the vehicle is repaired at a facility different from where it will be retested, the repair technician is required to complete an emissions-related repair data form (ERRD), which is to be given to the retest facility before the retest is begun.

Conditional passes only increase program effectiveness by encouraging partial repairs to vehicles that otherwise would not comply with program requirements. But conditional passes could be reducing program effectiveness by allowing partial repairs on vehicles that otherwise would either be fully repaired or permanently removed from the I/M area. It is difficult to determine which of these two effects the *Drive Clean* repair cost limits are having. The repair cost limit was raised from CDN$200 in July 2001 in phase 1, January 2003 in phase 2, and July 2004 in phase 3.

Conditional Pass Rates

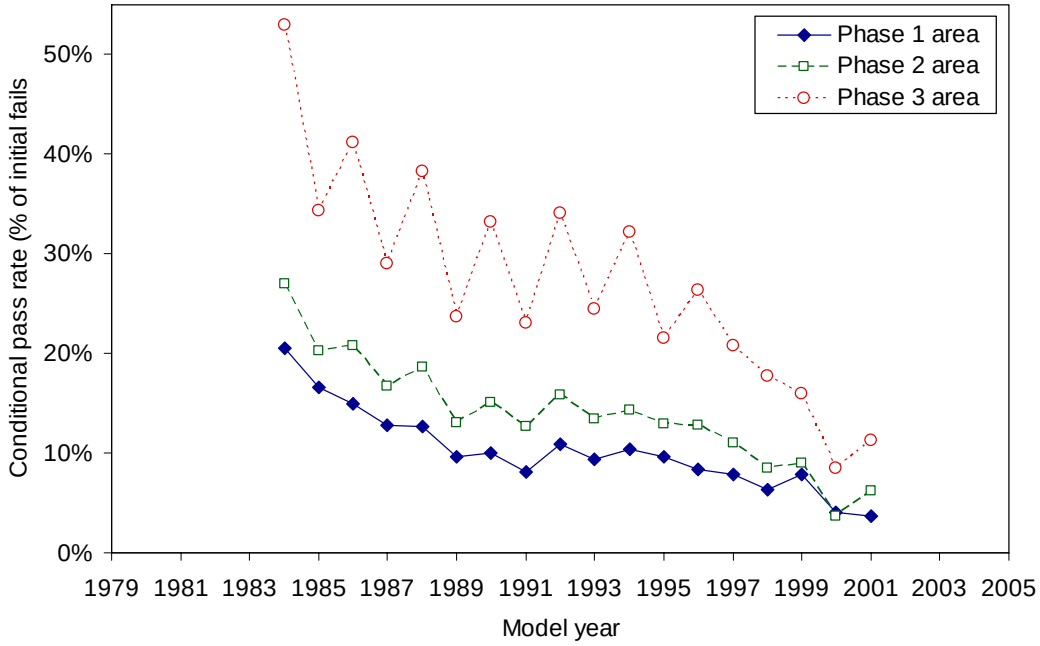
Table 5-6 shows the fail rate (as a percent of initial tests) and conditional-pass rate (as a percent of initial fails) for 2003-04, by vehicle type and phase.

Table 5-6. 2003-04 Fail and Conditional-Pass Rates (percent of initial fails), by Vehicle Type and Phase

Phase	Fail rate (percent of initial tests)			Conditional-pass rate (percent of initial fails)		
	Cars	LDTs	Total	Cars	LDTs	Total
Phase 1	9.7%	8.3%	9.3%	10.4%	11.9%	10.9%
Phase 2	10.0%	10.5%	10.2%	15.2%	16.5%	15.7%
Phase 3	10.3%	11.4%	10.7%	29.9%	32.3%	30.8%
Total	9.9%	9.7%	9.8%	15.3%	18.1%	16.3%

Figure 5-30 shows the conditional-pass rate for cars by phase and vehicle model year. Conditional-pass rates are higher in phase 3 than the other two phases because only about one-quarter of phase 3 vehicles have been subject to the higher repair cost limit adopted in mid-2004. In all three phases the conditional-pass rate decreases with increasing model year (or decreasing vehicle age).

Figure 5-30. 2003-04 Car Conditional Pass Rates, by Phase and Model Year



Figures 5-31 through 5-33 compare the fail-pass, conditional-pass, and no-final-pass rates, as a percentage of vehicles that failed their initial I/M test, by time in each program phase. The point when cutpoints were tightened and the repair cost limit was raised are noted in each figure. Each figure also shows the fail rate in each time period. Figure 5-34 shows that, in phase 1 from 1999 to mid-2001, the percent of conditional-pass cars decreases slightly (from 25% to 20%), while the percent of no-final-pass vehicles decreases slightly or holds constant. The repair cost limit was increased in phase 1 in mid-2001; the increase apparently resulted in a large reduction in the percent of conditional-pass vehicles, from 20% to 9%. It appears that most of this change resulted in a large increase in the percent of full-pass vehicles, from 72% to 80%, although the percent of no-final-pass vehicles did increase slightly from 8% to 10%.

This suggests that, in phase 1, the increase in the repair cost limit cut the conditional-pass rate in half, with most of the vehicles that would have received a conditional-pass obtaining a full pass, and only a portion (about 20%) not passing a retest. Cutpoints were tightened in phase 1 in 2003; this resulted in a reduction in full-pass vehicles, coupled with an increase in no-final-pass vehicles, and a slight increase, or no increase, in conditional-pass vehicles. This suggests that the change in cutpoints mostly results in vehicles that would have received a full-pass becoming no-final-pass vehicles. Note that the overall failure rate increased slightly as a result of the change in cutpoints in January 2003.

Figure 5-32 shows a similar trend for vehicles in phase 2, where both the increase in the repair cost limit and the tightening of cutpoints occurred at the beginning of 2003. Again, the conditional-pass rate is cut in half (14 percentage points), with most of the difference (11 points) increasing the full-pass rate, and some (3 points) increasing the no-final-pass rate. Figure 5-33 indicates that, in phase 3, the change in cutpoints in January 2003 has little effect on the conditional-pass or no-final-pass rate, while the increase in the repair cost limit in mid-2004 substantially reduces the conditional-pass rate (by 17 percentage points), with a substantial increase in the full-pass (9 percentage points) and no-final-pass (8 percentage points) rates.

Figure 5-31. Distribution of Initial Fails of Cars, by Final Result and Test Year – Phase 1

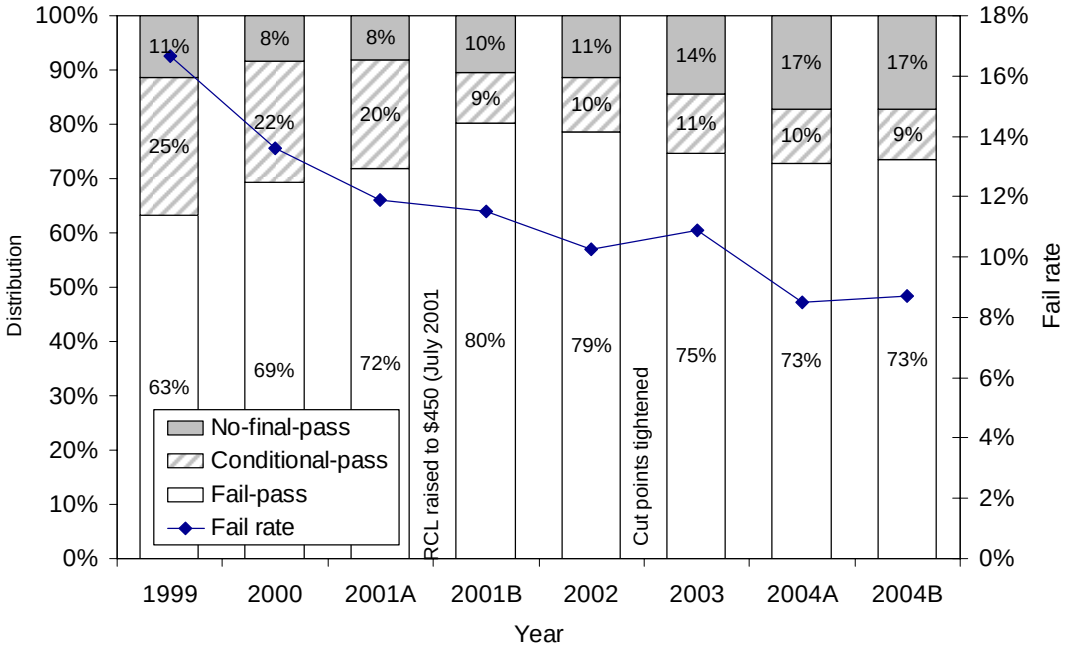


Figure 5-32. Distribution of Initial Fails of Cars, by Final Result and Test Year – Phase 2

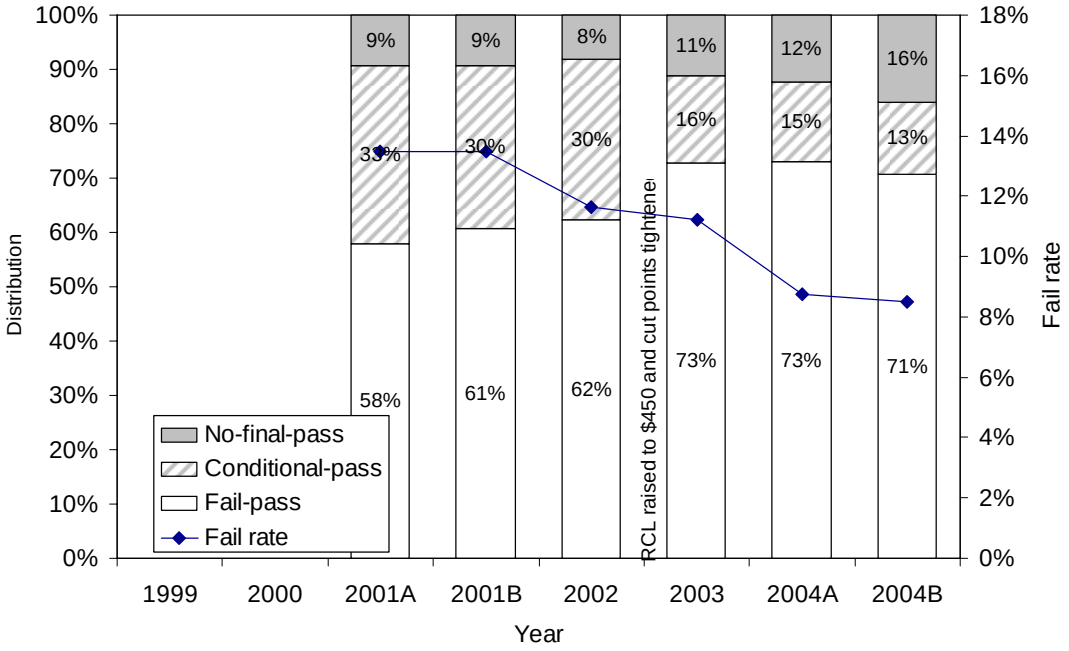


Figure 5-33. Distribution of Initial Fails of Cars, by Final Result and Test Year – Phase 3

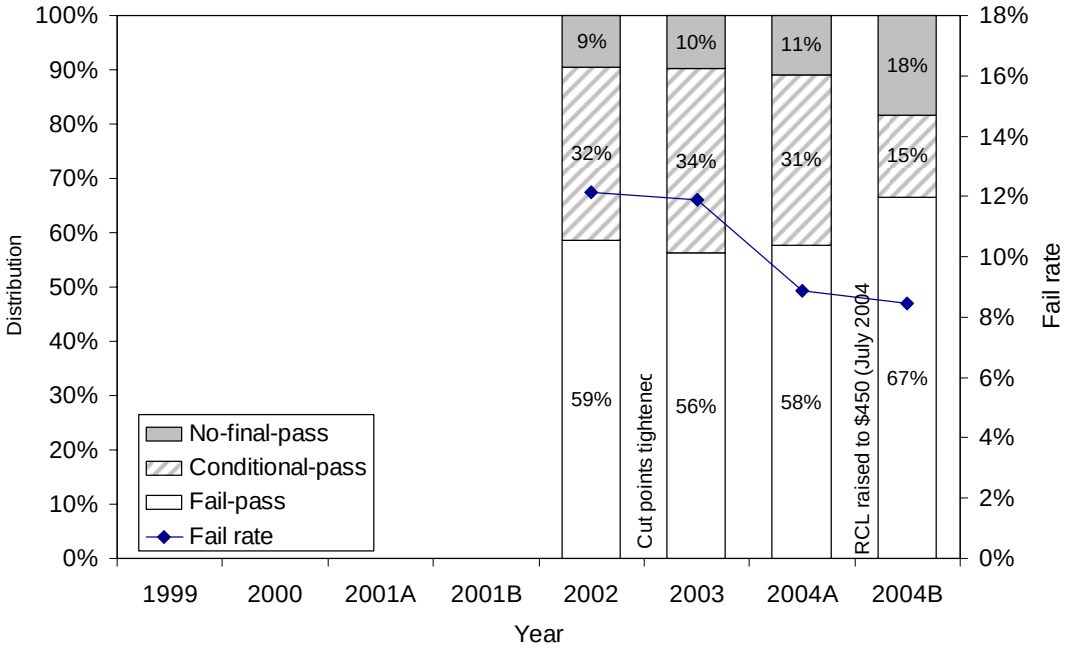
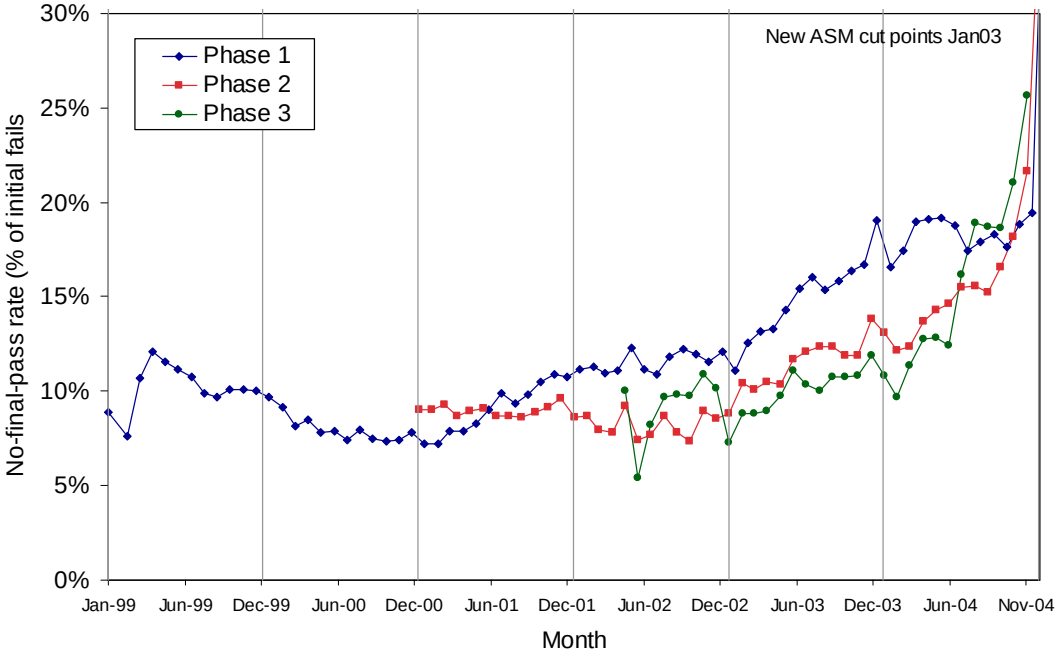


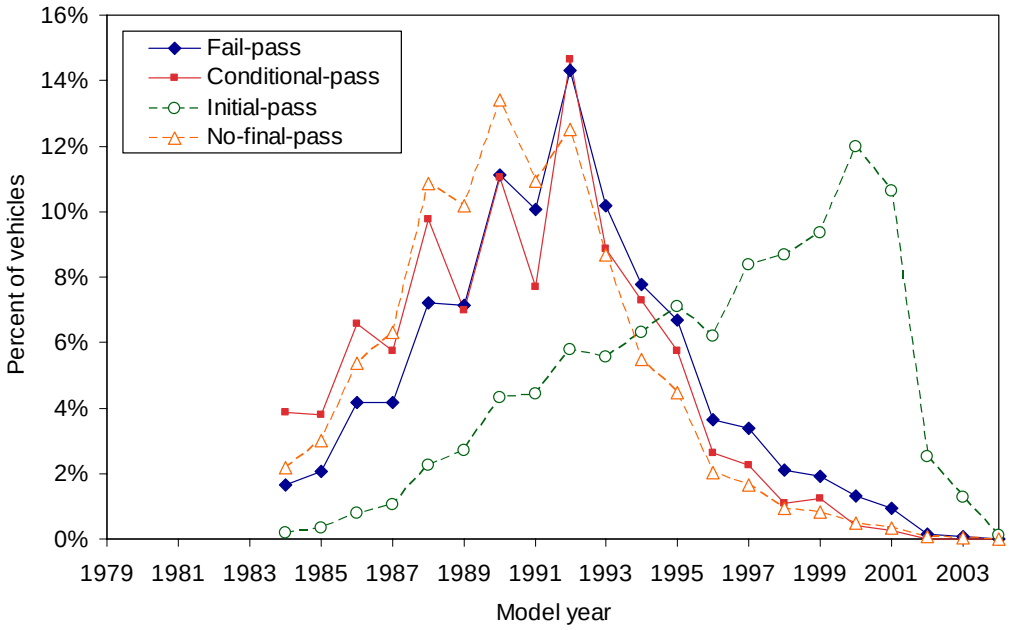
Figure 5-34. Car No-Final-Pass Rate, by Month and Phase



The no-final-pass rates increase in the last columns in Figures 5-31 through 5-33, in part because, as one approaches the end of the analysis period (January 2005), there is less time for a failing vehicle to obtain a passing retest (in other words, some of the no-final-pass vehicles initially tested in late 2004 eventually obtain a passing retest in early 2005, and become fail- or conditional-pass vehicles). However, Figure 5-34 shows that the increase in the no-final-pass rate begins in about mid-2001, well before the end of the analysis period. Because the no-final-pass rate increases fairly consistently after mid-2001, the effect of the increase of the repair cost limit on the percentage of no-final-pass vehicles is probably less than suggested in Figures 5-31 through 5-33. The trends in Figures 5-31 through 5-34 are similar for light trucks. Many of the no-final-pass vehicles had their registration renewed using a passing emission test generated by a different vehicle; for example, this practice accounted for nearly half of the no-final-pass vehicles in 2003. This practice was substantially curtailed in late 2004.

The repair cost limits were instituted to ease the burden of lower-income motorists in repairing their high-emitting vehicles. Lower-income motorists tend to own older cars than higher-income motorists. Figure 5-35 compares the model year distributions by emission test result; initial-pass cars are the youngest, with an average model year of 1996. The average fail-pass car is 4 years older (average model year of 1992), followed by the average no-final-pass car and conditional-pass car (average model year of 1991).

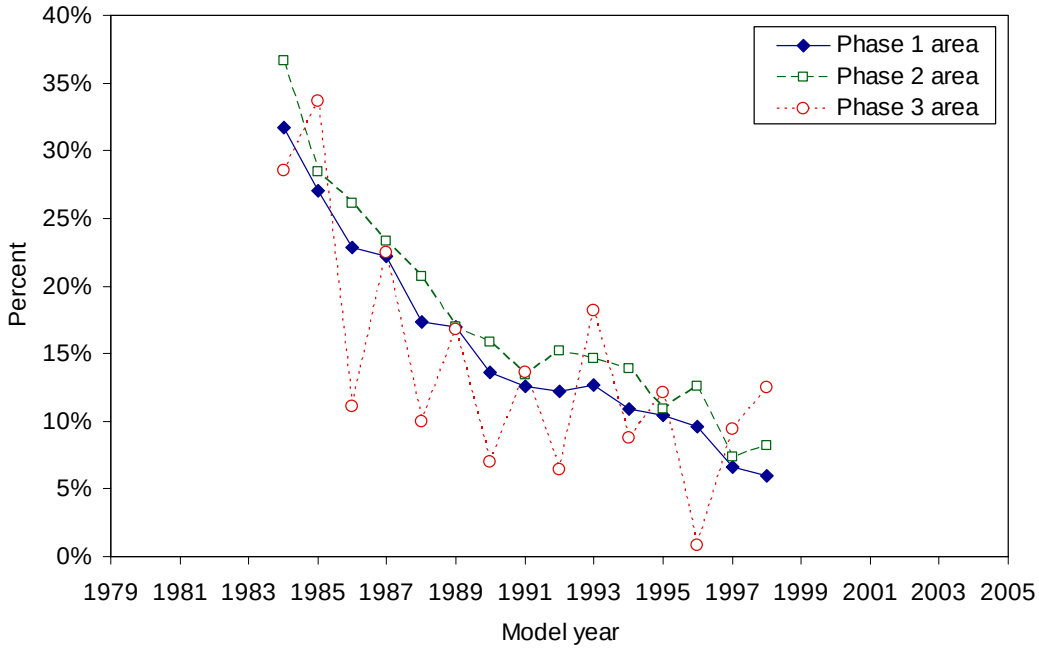
Figure 5-35. Model Year Distribution of Phase 1 Cars Tested in 2003-04, by Test Result



Repeat Conditional Passes

The *Drive Clean* program allows multiple waivers during the vehicle's lifetime. The unlimited number of conditional passes allowed may be unnecessarily reducing program effectiveness. Most other I/M programs allow only one waiver in a vehicle's lifetime, although Colorado allows multiple waivers as long as US$715 (CDN$900) worth of repairs have been documented. Of all of the conditional-pass vehicles tested in 2001-02, 16% received a second conditional-pass in 2003-04. Figure 5-36 shows the fraction of cars tested in 2001-02 and 2003-04 that received a conditional-pass in each test cycle, by phase and model year. The fraction of conditional-pass vehicles that received a second conditional-pass on their next test cycle decreases with increasing model year (or decreasing vehicle age), from over 30% for model year 1984 cars to about 10% for model year 1998 cars.

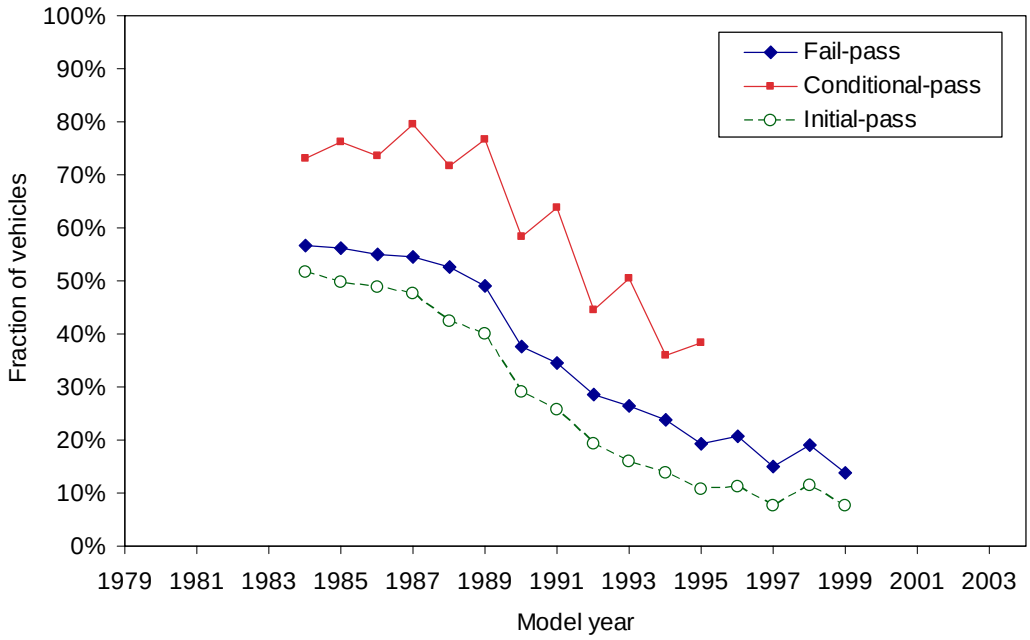
Figure 5-36. Fraction of 2003-04 Conditional-Pass Cars that were Conditional-Pass in Previous Cycle, by Phase and Model Year



The repeat conditional-pass rate is consistently slightly higher in phase 2 than in phase 1, particularly for even model years; this is likely because even model year vehicles tested in the first half of 2001 were subject to a CDN$200 repair cost limit. The repeat conditional-pass rates are extremely low for even model year cars in phase 3, because they were not subject to the CDN$450 repair cost limit that the odd model year cars were subject to.

A benefit of the repair cost limit is that it may permanently remove high-emitting vehicles from the *Drive Clean* areas. 69% of conditional-pass vehicles tested in 2002 were not tested in 2003 or 2004, as compared with 41% of fail-pass vehicles, and 22% of initial-pass vehicles, tested in 2002. Figure 5-37 shows the fraction of cars that were last tested in 2002 (and not in 2003-04), by test result and model year. The figure indicates that older model years are being removed from the program at a faster rate than newer model years, and that previous conditional-pass vehicles are being removed at a faster rate than full-pass or initial-pass vehicles. The fraction of conditional-pass vehicles last tested in 2002 is greater in phase 1 (69%) than in phase 2 or phase 3 (61%), which both had a CDN$200 repair cost limit in 2002.

Figure 5-37. Fraction of Cars that were Last Tested in 2002, by 2002 Test result and Model Year



The analysis of the previous increase in the repair cost limit suggests that the repair cost limit could be increased further, and a waiver granted only once in a vehicle's lifetime, without large numbers of vehicles circumventing program requirements. However, it is unknown to what extent additional increases in the repair cost limit will increase the number of vehicles circumventing program requirements.

5.2.3 Repair Data Entry Issues

Repair information is required to be entered each time a retest is performed on a vehicle that failed the initial test. However, we found that 40% of repaired vehicles (35% of full-pass, 0% of conditional-pass, and 87% of no-final-pass vehicles) in 2003-04 had no repair information. In addition, 39% of the repaired vehicles (46% of full-pass and no-final-pass vehicles, 1.2% of conditional-pass vehicles) had a repair record with zero or missing repair costs.

The current light duty OTU software is unable to retrieve repair data from previous *Drive Clean* tests. As a result, inspectors must enter all repair data completed during the current test cycle (actually performed within the previous 60 days). This is necessary so that the OTU can accurately calculate the total cost of repairs for comparison with the applicable Repair Cost Limit. This means that whenever multiple retests are performed, there will be duplicate repair data records uploaded to VETS.

Figure 5-38 shows the distribution of vehicles with repair records in 2003-04, by the cost of repair (in CDN$) and I/M result. Because of the duplicate repair records, we only included the most expensive repair record for each vehicle. Full-pass vehicles undergo an average of 1.23 rounds of repair, while conditional-pass vehicles undergo 1.68 rounds and no-final-pass vehicles 1.16 rounds (these figures include only those vehicle records with repair cost information entered). The figure indicates that reported repair costs are much higher for conditional-pass vehicles than full-pass vehicles; half of all conditional-pass vehicles spend over the repair cost limit before obtaining a conditional-pass, while 16% of all full-pass (and 21% of all no-final-pass) vehicles spend over the repair cost limit without obtaining a conditional pass. 12% of all conditional-pass, 3% of all full-pass, and 5% of all no-final-pass vehicles, spend over CDN$1,000 on repair, and 4% of all conditional-pass, 1.2% of all full-pass, and 1.8% of all no-final-pass vehicles spend over CDN$2,000. These reported repair costs appear to be high. We did not have time to distinguish between actual costs paid and recommended repair estimates for the conditional-pass vehicles.

Figure 5-38. Cumulative Emissions Distribution of Repair Costs (CDN$) for 2003-04 Repaired Cars (cost of the highest-cost round of repair reported)

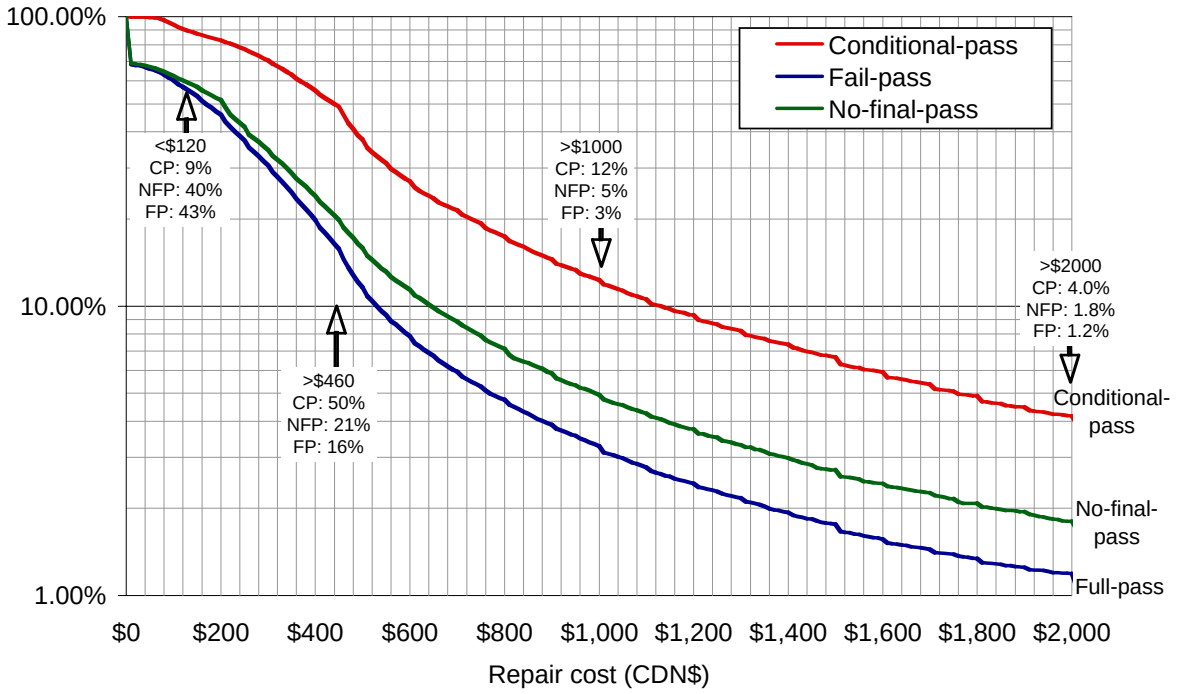


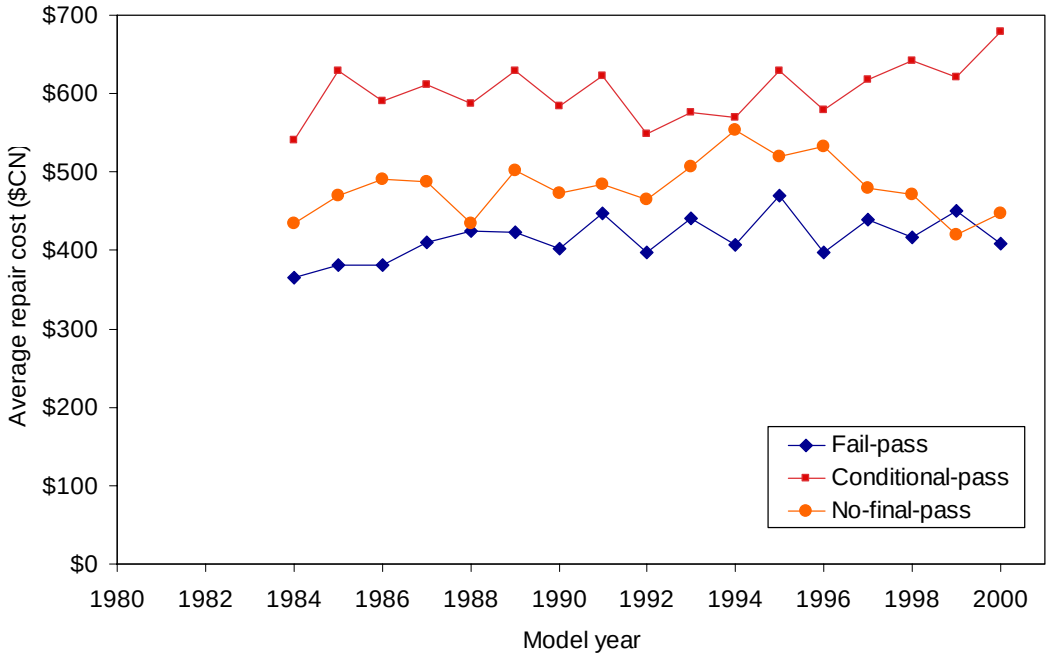
Table 5-7 shows the average repair costs in phase 1 in 1999-00 (when the repair cost limit was CDN$200) and in 2003-04 (after the limit was raised to CDN$450), by test result and vehicle type; missing and zero repair costs were excluded in calculating the average costs in the table. There is not much difference between repair costs for conditional-pass and full-pass vehicles in 1999-00 (although attempted repairs to no-final-pass vehicles cost more). However, after the repair cost limit was raised, the average repair cost for conditional-pass vehicles is greater than that for full-pass vehicles (and that for no-final-pass vehicles). Note that surveys by DesRosiers Automotive Consultants indicate that total vehicle repair costs average about CDN$1,000 per year.

Table 5-7. Average Repair Cost (CDN$) for Phase 1 Light-Duty Vehicles (cost of the highest-cost round of repair reported), by Year, Vehicle Type and I/M Result

Years	Vehicle type	Conditional-pass	Full-pass	No-final-pass
1999-00	Cars	$411	$415	$457
	LDTs	$403	$422	$499
	Total	$409	$417	$464
2003-04	Cars	$588	$416	$482
	LDTs	$651	$430	$540
	Total	$606	$419	$497

Figure 5-39 shows the average cost of repair for cars repaired in 2003-04, by model year and I/M result. Here we see again that the cost to repair conditional-pass cars is higher than for full-pass cars. Repair costs are remarkably similar by model year.

Figure 5-39. Average 2003-04 Repair Costs (CDN$) for Phase 1 Cars (cost of the highest-cost round of repair reported), by Model Year and I/M Result



Our analysis of repair cost data suggests that, for many vehicles, the data are not reported accurately, particularly for vehicles that received a conditional pass. In US I/M programs the repairs and payments are verified for each vehicle that receives a waiver. In centralized programs, the repairs are typically verified by a state employee inspector at certain or all centralized test facilities; in decentralized programs, the repairs are verified by a network of contractor-run referee facilities. In the *Drive Clean* program (and the BC program) vehicle repair records are subject to audit. If there is little verification of repairs performed and payments made, there is little incentive for technicians to enter accurate repair cost data, and technicians may be tempted to inflate actual or recommended repair costs in order to fraudulently obtain conditional-passes for vehicles. DCO should consider changing its procedures, so that all vehicle repairs, and expenditures on repairs, should be verified before a conditional pass is granted. This would require DCO to set aside resources for this purpose.

5.2.4 Test Frequency

Light-duty vehicles are tested biennially in the *Drive Clean* program, with heavy-duty vehicles tested annually. Several U.S. I/M programs, such as those in Phoenix and California, that added their enhanced I/M program to an existing basic program, test vehicles in the enhanced area on a biennial basis, and vehicles in the basic area on an annual basis. And the British Columbia program requires that 1992 and newer light-duty vehicles get a biennial IM240 test, while 1991 and older vehicles get an annual ASM test. EPA originally recommended biennial testing for centralized IM240 programs because of the cost of the test equipment, the inconvenience of waiting at a small number of centralized stations for an inspection, and the perceived improved accuracy of the mass-emissions test in identifying high emitters. The tradeoff is a more thorough test every two years as opposed to a less accurate test every year.

Some I/M programs have considered testing more frequently certain classes of vehicles suspected of being high emitters. For example, from 1995 to 2000 Arizona used an extensive network of remote sensing units to identify suspected high emitters for an off-cycle I/M test. And New York City requires that all taxis must be tested three times a year to retain their medallion (or permit) to operate in the city. Increasing the test frequency of suspected high emitting vehicles makes sense, as almost half of vehicles that failed their initial inspection in the previous test cycle fail their next inspection as well, as demonstrated above.

Ontario requires that before a vehicle is sold or changes ownership it must pass (and not conditionally-pass) an off-cycle inspection (if the previous on-cycle inspection has expired). This change of ownership requirement allows analysis of repeat fail rates as a function of time since the vehicle passed its previous test cycle. The analysis may be affected by the fact that owners may be more likely to sell vehicles with an emissions problem. This means that the off-cycle test sample may not be random but may be skewed towards vehicles with higher emissions. Figure 5-40 shows the distribution of vehicles tested in 2004, by the number of months since the previous test cycle. The blue filled diamonds show the distribution of vehicles, on the left-hand scale, while the red open squares show the cumulative distribution of vehicles, on the right-hand scale. 54% of all vehicles tested in 2004 had a previous test cycle 23 to 27 months prior to the 2004 cycle. This is consistent with the biennial test cycle of the *Drive Clean* program. Note that a relatively large fraction of vehicles had their previous cycle around one year prior to the 2004 cycle. This could be due to off-cycle resale testing in the previous calendar year.

Figure 5-40. Distribution of Phase 1 Vehicles Tested in 2004, by Months Since Previous Cycle

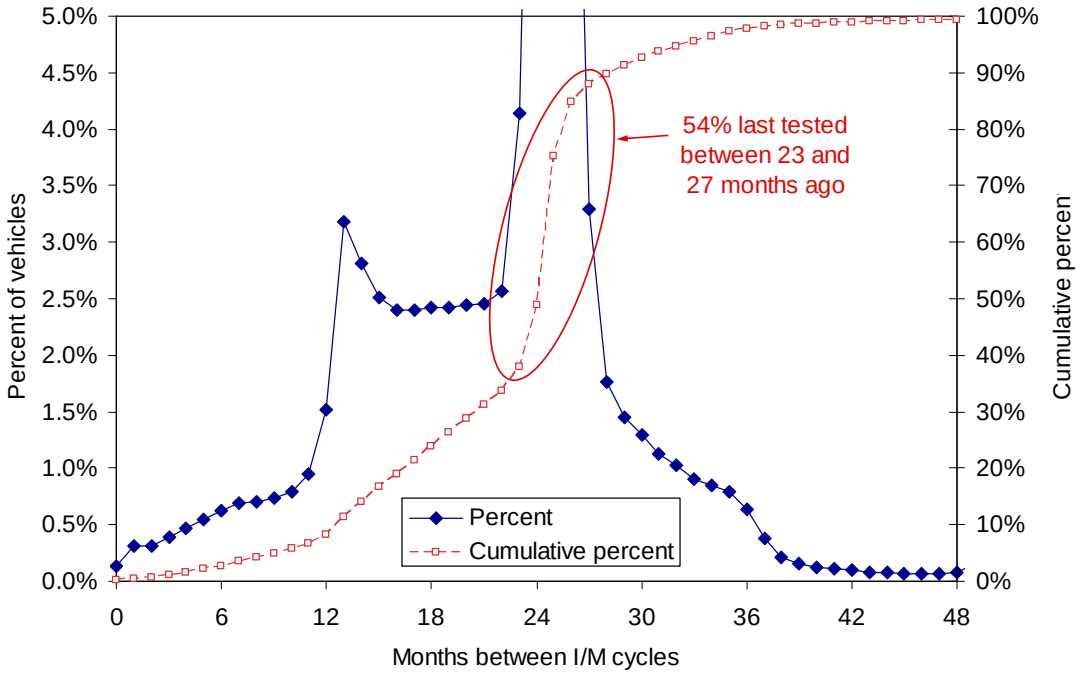


Figure 5-41 shows the 2004 fail rate by time since the previous test cycle, by the result of the previous cycle. As discussed above, about 60% of conditional-pass vehicles, and 40% of fail-pass vehicles, fail their next I/M test.

Figure 5-41 indicates that, if the fail-pass vehicles were tested shortly after the last passing retest in their previous cycle, about 30% of them would fail, while about 50% of conditional-pass vehicles would fail if tested shortly after their previous cycle. Figure 5-41 suggests that most emissions deterioration occurs soon after the previous test cycle.

For the 30% of the fail-pass vehicles that fail soon after a “repair”, many issues need to be considered and further study is needed to form definitive conclusions. However, improving repair durability should be a key goal for all I/M programs. California is in the process of adopting this recommendation as part of their Smog Check program. As previously shown, older vehicles have a much higher fail-pass-fail rate than newer vehicles. Since this may due to their higher overall probability of failing, this may suggest older vehicles should be tested more frequently.

Figure 5-41. Fail Rate of Phase 1 Vehicles Tested in 2004, by Time Since Last Pass

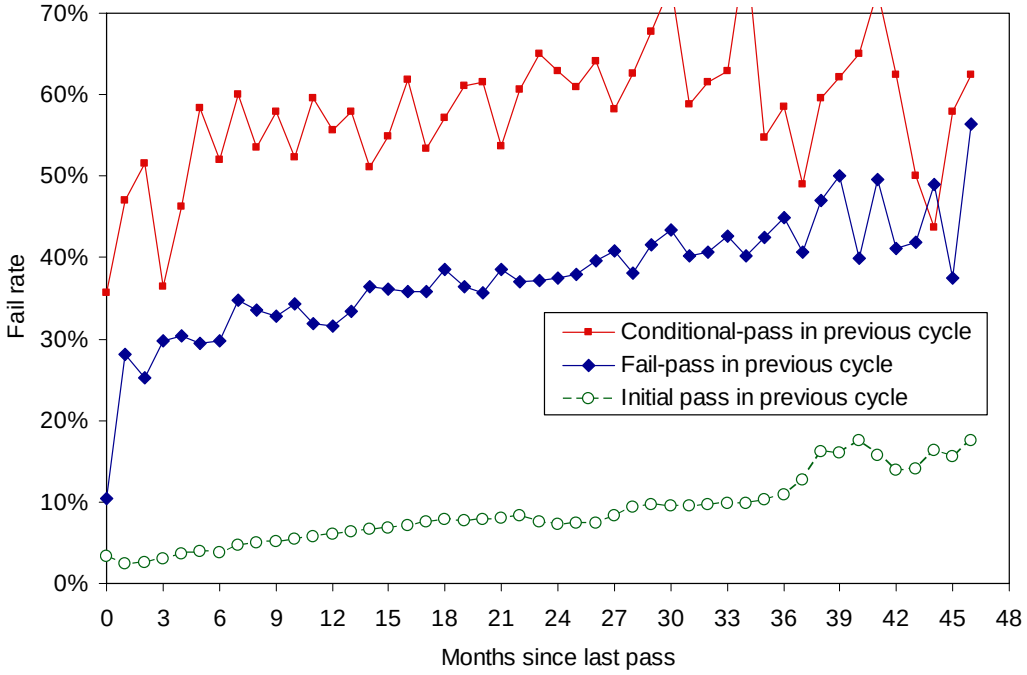


Figure 5-42 shows similar trends in two centralized I/M programs, which are considered less prone to test fraud than decentralized programs. Figure 5-43 shows a similar trend for OBDII vehicles, which presumably are easier to repair because of the detailed diagnostic information available to technicians.

Figure 5-42: Failure Rates in Three I/M Programs by Times Since Previous Test Cycle, by Previous I/M Result

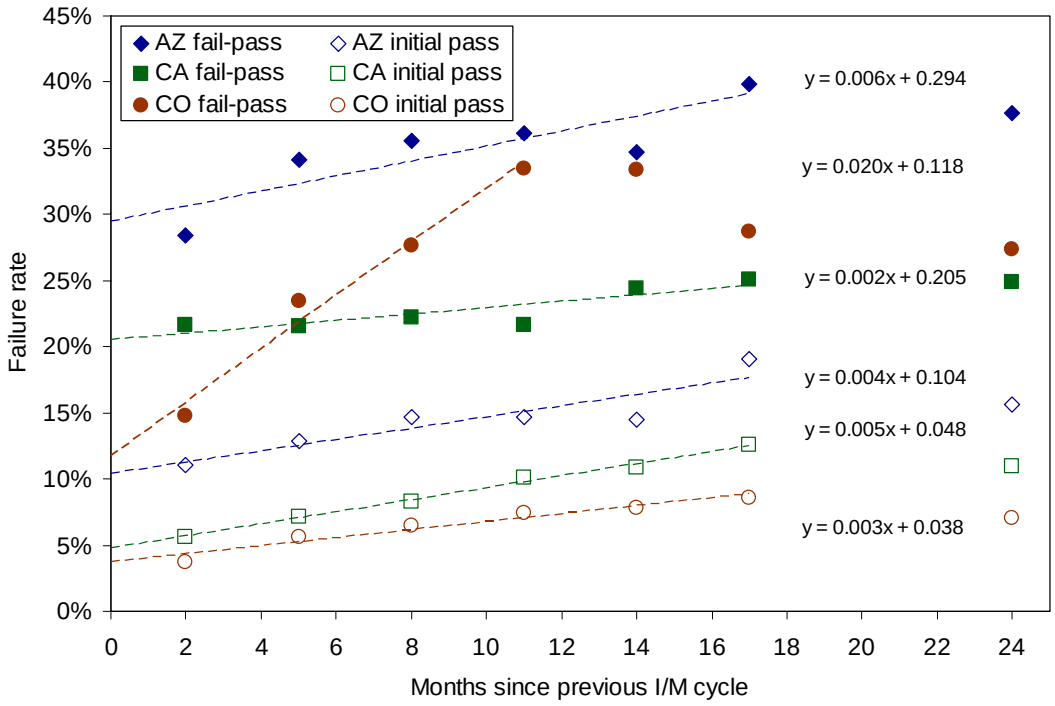
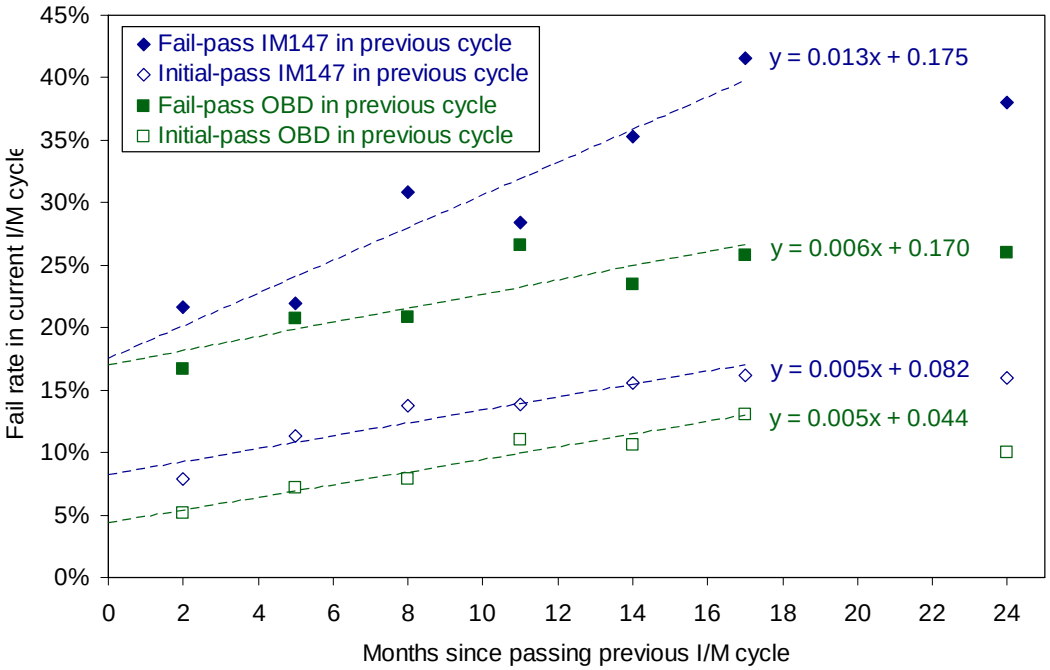


Figure 5-43: Failure rates in Arizona by Times Since Previous Test Cycle, by Vehicle Technology Type and Previous I/M Result


Fail-pass IM147 in previous cycle
Initial-pass IM147 in previous cycle
Fail-pass OBD in previous cycle
Initial-pass OBD in previous cycle
y = 0.013x + 0.175
y = 0.006x + 0.170
y = 0.005x + 0.082
y = 0.005x + 0.044
Fail rate in current I/M cycle
Months since passing previous I/M cycle

Note that in Figures 5-42 and 5-43 the failure rates decrease noticeably around two years after the previous test cycle. This suggests that the vehicles given off-cycle tests in these jurisdictions have higher emissions than vehicles given biennial tests, and may not be representative of the entire I/M fleet; however, in Figure 5-41 there is no such dip in the Ontario fail rates around two years after the previous cycle.

Rapid emissions deterioration, implied by the high failure rates soon after vehicles pass their previous test cycle, occurs in all I/M programs, centralized and decentralized alike, and suggests that some of the initial emission benefit from vehicle repairs is quickly lost. One potential solution to this problem is more frequent testing of vehicles suspected of having high emissions, such as older vehicles that failed the initial test of their previous inspection, and high mileage vehicles, such as taxi cabs and local service delivery fleets.

5.3 HDV Program – Effectiveness Evaluation

5.3.1 HDV Program Statistics

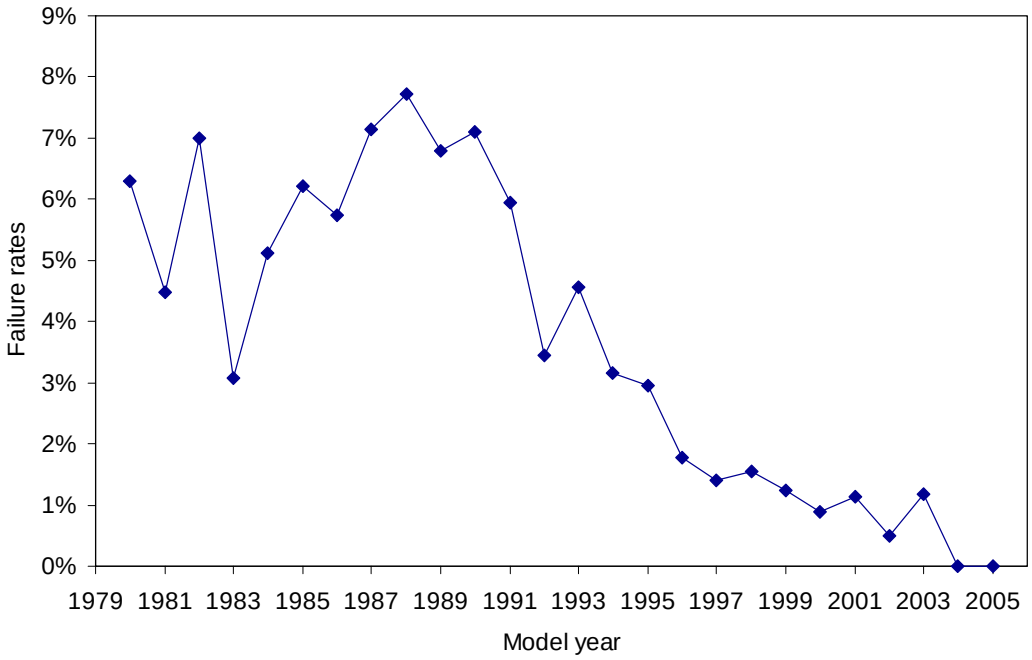
Table 5-8 shows the failure rate for heavy-duty diesel vehicles by year. Because a new model year is added to the program in each successive calendar year, one expects failure rates to decline over time. Table 5-8 also shows the failure rates for 1996 and older heavy-duty diesels only; these model years were required to be tested in each calendar year. Failure rates decreased from 1999 through 2003, but have increased in 2004, presumably because of the tighter cutpoints adopted in April 2004.

Table 5-8. Failure Rate for Heavy-Duty Diesel Vehicles, by Year

	Fail rate					
Model years	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
All	5.0%	4.7%	3.1%	2.3%	2.0%	2.8%
1996 and older	5.2%	5.3%	3.9%	3.2%	3.0%	4.7%

Figure 5-44 shows the 2004 failure rate for heavy-duty diesel vehicles by model year. 1980 and older vehicles are combined as model year 1980 in the figure. About 6% to 8% of 1991 and older heavy-duty diesels fail the opacity test; for 1992 and newer vehicles, the failure rates start decreasing as vehicle model year increases (or age decreases).

Figure 5-44. 2004 Heavy-Duty Diesel Vehicle Failure Rates, by Model Year



5.3.2 HDV Program – Strengths and Weaknesses Evaluation

This section describes the *Drive Clean* heavy-duty vehicle program and assesses what aspects of the program are effective in reducing emissions, and what aspects can be improved. We also compare aspects of the *Drive Clean* program with those of other I/M programs.

Table 5-9 summarizes heavy-duty diesel testing in other I/M programs. Although several other jurisdictions include heavy-duty diesel vehicles in their I/M programs, these programs have not been as extensively analyzed as light-duty vehicle programs.

5.3.2.1 Model Years – Design and Assess Appropriateness, what Model Years do Other Programs Test

Drive Clean requires that all heavy-duty vehicles older than two years old be tested. Most other programs that include heavy-duty diesel testing require that all vehicles be tested.

Table 5-9. Heavy-Duty Diesel Testing in I/M Programs

State	Start Date	Model Years	Test Procedure	Frequency	Cutpoints (percent opacity)
AZ (Phoenix)	1999	1967+	SAE J1667	Annual	67-90: 55%; 91+: 40%
AZ (Tucson)	1999	1967+	Lug-down	Annual	< 2000 ft altitude: 20% 2000-4000 ft altitude: 30% > 4000 ft altitude: 40%
CO	1987	All	Loaded mode	Annual	naturally-asp.: 35% turbo-charged: 20%
ID		1965+	Snap idle		65-74: 70%; 75-91: 55%; 92+: 40%
ME			Snap idle		<74: 70%; 74-90: 55%; 91+: 40%
MD	1993	All	J1667		<74: 70%; 74-90: 55%; 91+: 40%
MA	2001		J1667	Biennial	<91: 55%; 91+: 40%
NV	1996	All			all: 70%
NH			Snap idle		<74: 70%; 74-90: 55%; 91+: 40%
NJ	1997	All	J1667	Annual	<74: 70%; 74-90: 55%; 91+: 40%
NY	1999	All	Snap idle	Annual	<74: 70%; 74-90: 55%; 91+: 40%
PA	1999 Pilot				Never implemented
UT		All	J1667	Annual	all: 70%
VT			Snap idle		<91: 55%; 91+: 40%
WA	1993	1968+	J1667		68-73: 70%; 74-91: 60%; 92+: 40%
ONT			J1667	Annual	<91: 40%; 91+: 30%

5.3.2.2 Program Area

Unlike the light-duty program, the heavy-duty diesel program encompasses the entire province of Ontario, since the start of required testing in mid-November 1999. I/M programs in other jurisdictions that include heavy-duty diesel vehicles typically encompass the same area for both light-duty and heavy-duty fleets; *Drive Clean* is unique in that heavy-duty diesel vehicles registered throughout the province are subject to the program. However, many heavy-duty diesel vehicles that regularly drive in or through Ontario are not registered in the province, and therefore are not subject to *Drive Clean* testing. This is a problem common to all I/M programs. One method to estimate the fraction of heavy-duty diesel vehicles driving in, but not registered in, Ontario is to compare the ratio of registered heavy-duty diesel to registered light-duty vehicles in several I/M jurisdictions; this analysis was outside the scope of the current study.

5.3.2.3 Test Technology

The *Drive Clean* program uses the two-speed idle test for heavy-duty (over 4500 kg test weight) non-diesel vehicles, and an opacity smoke test for heavy-duty diesel vehicles. If it is feasible and affordable, a diesel I/M program to reduce both NO_x and PM would be an

improvement to the current I/M program and would better address the contribution of diesel emissions to ozone formation in Ontario. Previous research in Australia and Colorado[29] indicates that repairs for opacity may increase NO_x emissions, especially for older heavy-duty diesel vehicles. However, no I/M programs are currently testing NO_x and PM emissions from heavy-duty diesel vehicles. In addition, the BC AirCare program is setting up a single test lane that will monitor NO_x during opacity tests in order to collect data that may shed light on the implications of NO_x impacts in their diesel I/M program.

5.3.2.4 Test Fees

DCFs can charge the market price for tests of heavy-duty diesel vehicles; the current average fee is CDN$75 (US$60). DCO receives CDN$15 (US$12) for each passing heavy-duty diesel test. Because most heavy-duty diesel fleet vehicles are self-tested (i.e. the facility responsible for maintaining the fleet is a certified DCF that performs *Drive Clean* testing on the fleet), the actual cost of testing heavy-duty diesel vehicles is uncertain. Presumably this testing could be done as part of a regular vehicle maintenance schedule. Arizona charges CDN$32 (US$25) for a heavy-duty diesel test.

5.3.2.5 Cutpoints

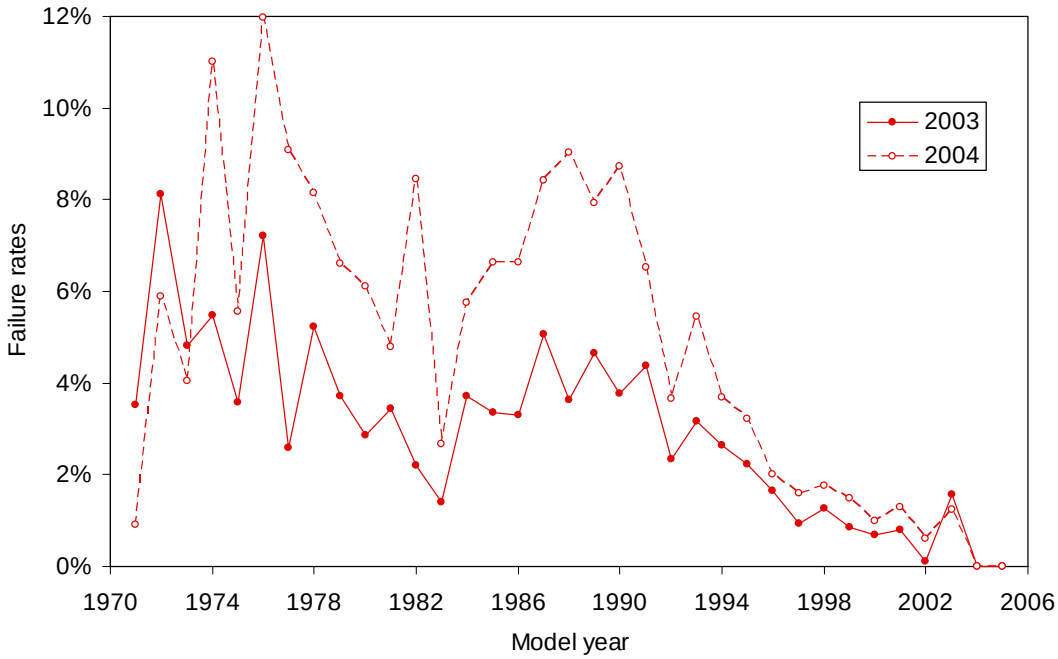
Table 5-10 shows the opacity cutpoints for heavy-duty diesel vehicles. The opacity cutpoints for heavy-duty diesel vehicles were tightened in April 2004; the change in the cutpoints increased the failure rate for heavy-duty diesel vehicles tested in April through December from 2.1% in 2003 to 3.2% in 2004. Figure 5-45 shows that the change in cutpoints consistently increased failure rates for all model years; however, the failure rates increased dramatically for 1993 and older vehicles, in some cases doubling.

Table 5-10. Opacity Test Cutpoints for Heavy-Duty Diesel Vehicles

Vehicle type	Model years	Sep 99 through Mar 04	Apr 04 through Mar 05	Apr 05 on
School bus	1990 and older	55%	35%	30%
	1991 and newer	40%	35%	30%
Other	1990 and older	55%	45%	40%
	1991 and newer	40%	35%	30%

[29] Robert L. McCormick, et. al., "Quantifying The Emissions Benefit of Opacity Testing And Repair of Heavy-Duty Diesel Vehicles." Final report to Colorado Department of Public Health and Environment, Denver, Colorado, July 23, 2001.

Figure 5-45. Fail Rate of Heavy-Duty Diesel Vehicles Tested in April Through December, by Year and Model Year



The opacity cutpoints were tightened again in April 2005. A DCO analysis of heavy-duty diesel failure rates indicates that the change in cutpoints increased the failure rate from 3.6% from January through March 2005 to 5.8% in April 2005.

The current *Drive Clean* opacity cutpoints for heavy-duty diesel vehicles are more stringent than those used in any other I/M program that tests heavy-duty diesel vehicles.

Table 5-11 shows the cutpoints for the two-speed idle test given to heavy-duty non-diesel vehicles.

Table 5-11. Two-Speed Idle Test Cutpoints for Heavy-Duty Non-Diesel Vehicles

Model years	HC (ppm)	CO (%)	Visible smoke (seconds/minute)
1969 and older	1000	8.0	5
1970-74	800	6.5	5
1975-79	400	4.0	5
1980-87	300	3.0	5
1988-97	220	1.2	5
1998 and newer	200	1.0	5

5.3.2.6 Repair Effectiveness

Because the cutpoints for heavy-duty diesels were tightened in April 2004, we analyzed the effectiveness of repairs to heavy-duty vehicles tested in 2003. Table 5-12 shows the fail- and no-final-pass rates of heavy-duty diesels tested in 2003, by the result of their previous I/M cycle. The 2003 failure rate for heavy-duty diesels was 2.0%; the failure rate was slightly lower (1.7%) for vehicles that passed the initial test of their previous inspection, slightly higher (3.1%) for vehicles that had not been previously tested, and much higher (17%) for vehicles that failed the initial test of their previous inspection.

Table 5-12. 2003 Fail- and No-Final-Pass Rates for Heavy-Duty Diesel Vehicles, by Result of Previous I/M Cycle

Previous I/M cycle	Fail rate	No-final-pass rate (% of initial fails)
Not tested	3.1%	24.7%
Fail-pass	17.1%	5.3%
Initial-pass	1.7%	5.5%
Total	2.0%	8.8%

Figure 5-46 shows the failure rate by model year and previous I/M result; while the failure rate for previous initial-pass and untested vehicles decreases with increasing model year (and decreasing age), there is no trend in the failure rate by model year for fail-pass vehicles in the previous cycle. As with light-duty vehicles, a large portion (almost 20%) of heavy-duty diesel vehicles that failed their previous initial inspection fail their next initial inspection roughly one year later. This suggests that the previous repairs were not entirely effective for many vehicles.

Emission levels can also vary on either side of the cutpoints. These vehicles are usually referred to as “marginal emitters”. Such vehicles are likely to have repairable emission defects but may “just fail” on one test and “just pass” on the next test. What is being observed in many cases is the natural test-to-test variability of vehicles with certain emission control defects.

Figure 5-46. Fail Rate of Heavy-Duty Diesel Vehicles Tested in 2003, by Previous I/M Result and Model Year

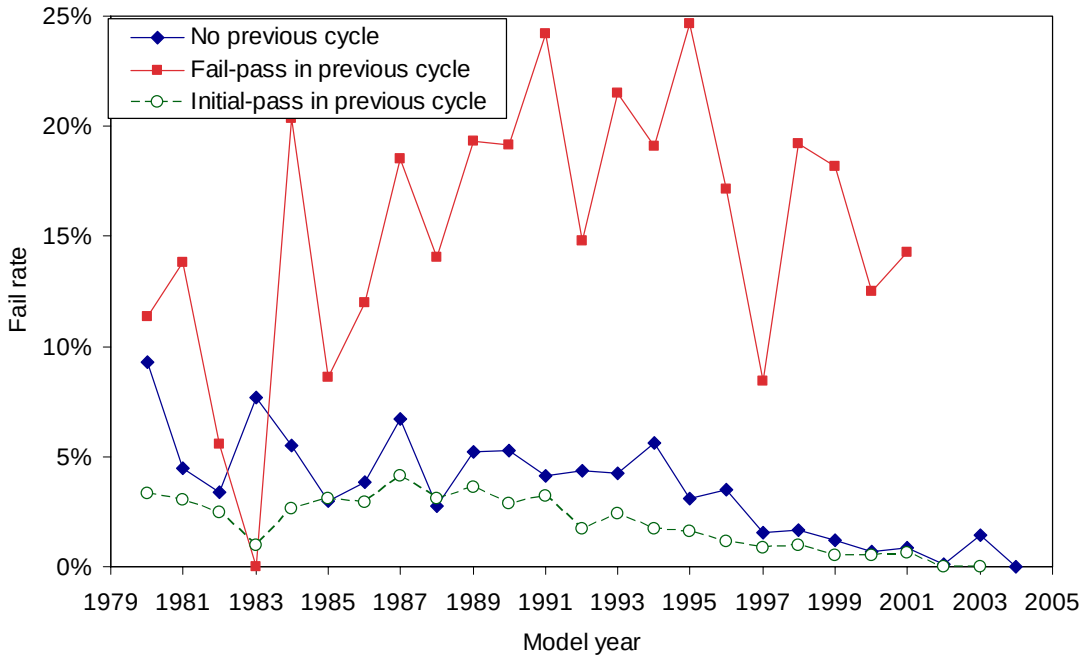


Table 5-12 also indicates that 9% of heavy-duty diesels tested in 2003 failed and did not pass a retest through January 2005. The no-final-pass rate is much higher for vehicles not previously tested (25%) than for vehicles that were also tested prior to 2003 (5%).

5.3.2.7 Test Frequency

As shown in Table 5-9, most I/M programs that regularly test heavy-duty diesel emissions require an annual test. Table 5-12 indicates that vehicles that were fail-pass in their previous I/M cycle have a much higher failure rate (17%) than vehicles that were initial-pass in their previous I/M cycle (2%).

In January 2005 heavy-duty diesel vehicles that pass with opacity readings below 20% are allowed to forego their next annual inspection, and be tested biennially. In the future the repeat fail rates of fail-pass heavy-duty diesel vehicles tested annually can be compared with those of heavy-duty diesel vehicles tested biennially, to estimate the effect of more frequent testing on the emissions deterioration rate between I/M tests.

We compared the 2003 and 2004 opacity test results for HDDVs to assess the effectiveness of biennial testing of HDDVs with opacity readings less than 20%. Table 5-13 shows the number of 2003 initial test result of HDDVs tested in 2002, by the result and opacity

reading of the 2002 test. 2002 fail-pass HDDVs with 2002 opacity readings less than 20% had a 14% failure rate in 2003, while similar vehicles with a final 2002 opacity greater than 20% had a 20% failure rate in 2003. On the other hand, 2002 initial-pass HDDVs with low 2002 opacity readings had a much lower 2003 failure rate (0.9%) than 2002 initial-pass HDDVs with high 2002 opacity readings (5.4%). We also looked at the fraction of 2003 failures that had final 2002 opacity readings less than 20%; 40% of the 2003 failures had a final 2002 opacity reading of less than 20%. Table 5-13 shows that this rate is similar for HDDVs that were fail-pass or initial-pass in 2002. If any vehicles are exempted from their next annual opacity test, it should be those vehicles that passed their initial opacity test with opacity less than 20%; HDDVs that passed a retest with opacity less than 20% had about the same failure rate on their next test as HDDVs that passed a retest with opacity greater than 20%.

Table 5-13. Heavy-Duty Diesel Vehicles that Fail 2003 Test, Based on 2002 Result and Opacity Reading

2002 result	2002 opacity	2003 initial test result		Total	2003 fail rate	Percent of 2003 failures that were <20 in 2002
		Fail	Pass			
Fail-pass	<20	161	967	1,128	14%	34%
	>=20	314	1,263	1,577	20%	(161/475)
	Total	475	2,230	2,705		
Initial-pass	<20	841	96,129	96,970	0.9%	40%
	>=20	1,247	21,916	23,163	5.4%	(841/2088)
	Total	2,088	118,045	120,133		

We suggest that DCO more thoroughly evaluate emissions deterioration and repeat fail rates in a heavy-duty diesel vehicle pilot program. DCO can then revisit biennial testing for heavy-duty diesel vehicles that pass their previous *Drive Clean* test with emissions less than 20% opacity, as well as consider more frequent testing of heavy-duty diesel vehicles with particularly high emissions.

5.4 Compliance

Like most I/M programs, *Drive Clean* does not allow a vehicle's registration to be renewed until it has passed a *Drive Clean* inspection, if required. Requiring proof of a passed *Drive Clean* test is the program's strongest compliance tool. The DCO establishes program rules and policies and is responsible for the maintenance of program integrity. The QA/QC contractor (ProtectAir) plays a key compliance-related role by undertaking initial accreditation audits and ongoing compliance audits at DCFs and where the situation warrants, also issues Correction Notices and initiates lockouts.

The *Drive Clean* program is designed to achieve the highest standard of compliance with the Performance Contract at *Drive Clean* facilities. The program imposes specific, detailed operational requirements on facilities conducting emissions tests and repairs and monitors their performance through a series of audits.

Not all non-compliance is fraud; non-compliance includes fraud as well as breaches of standard operating procedures. Fraud is understood to include any deliberate act to circumvent program rules, generally for personal profit. Other far more common forms of non-compliance include breaches of standard operating procedures, generally due to carelessness or disregard for the rules. *Drive Clean* has systems in place and takes an appropriate action to deal with both types of non-compliance. To counteract attempts by the public to "beat the system", three design features were incorporated into the initial design of the emissions testing and repair service network;

1) clear accountability,

2) comprehensive system to measure *Drive Clean* facility performance,

3) access to effective tools to address non-compliance.

In this section, we examine the following two key aspects of *Drive Clean* program compliance:

1) DCF compliance - failure by a DCF to comply with one or more of the obligations in its Performance Contract (e.g. also includes all federal, provincial and municipal laws and regulations as well as *Drive Clean* standard operating procedures) and,

2) Registration fraud - failure of a vehicle owner to comply with MTO registration requirements (e.g. deliberate procurement and use of invalid Vehicle Inspection Report (VIR) pass to support unlawful vehicle licence transactions (transfers and/or renewals))

5.4.1 DCF Compliance

5.4.1.1 DCF Compliance Program

In this section we assess the tools and procedures in place to measure and correct incidents of non-compliance among the accredited network of DCFs. To become an accredited DCF, facility owners must enter into a Performance Contract that outlines their obligations including adherence to standard operating procedures. Prior to conducting any emissions tests

and/or repairs, facilities are audited by the QA/QC contractor (ProtectAir) to confirm compliance with all program requirements. After accreditation, DCFs are audited on a regular basis using either overt or covert audits. A risk and performance auditing system was implemented in January 2003 in order to optimize audit scheduling by targeting audit activity at facilities with the weakest performance records.

The kinds of tools that exist to address non-compliance at DCFs include; 1) immediate face-to-face auditor feedback, 2) correction notices, 3) lockouts, 4) mandatory performance interviews, 5) letters of reprimand, 6) inspector and/or repair technician certification revocation, 7) DCF suspension of accreditation, 8) DCF termination of accreditation and 9) referral to IEB for investigation that may warrant charges and prosecution against a DCF or DCF staff. In addition, the kinds of tools that exist to address non-compliance of *Drive Clean* regulations by individuals who are not employed at DCFs include on-road tickets/fines, charges under the *Environmental Protection Act* and possible prosecutions.

Overt audits include an assessment of compliance with accreditation requirements, an evaluation of proficiency of inspectors conducting emissions tests and an assessment of the *Drive Clean* facility staff program knowledge and customer service skills. The emissions testing equipment is also checked to confirm proper calibration. The QA/QC contractor performs at least one overt audit on each DCF each year.

Covert audits are also used to assess DCF compliance. In such cases, an undercover auditor and a QA/QC auditor's vehicle are used as a means to evaluate DCF proficiency and performance. The QA/QC auditor vehicle is inspected by the auditor before and after undergoing DCF service to gather compliance information in support of the targeted facility evaluation.

The results of an audit determine the nature of the follow-up action. The auditor can issue a correction notice requiring the immediate correction of minor matters or in some circumstances, for example when the equipment is improperly calibrated; impose a lockout preventing any further tests from being conducted. The most serious matters are referred to the DCO for a performance interview, suspension or termination of facility accreditation, and/or investigation by the Investigations and Enforcement Branch of suspected violations of the *Environmental Protection Act* which may result in charges being filed.

On January 4, 2005 the DCO implemented a revised *Drive Clean* Compliance Guideline for Light Duty Vehicle (LDV) *Drive Clean* Facilities (DCFs) that replaced the existing guideline contained in the standard operating procedures. The enhanced Compliance Guideline contains new rules that are designed to enable stricter and faster enforcement. The main elements of the

Compliance Guideline include quicker terminations for some first events of non-compliance such as generating fraudulent pass certificates, quicker suspension process for incidents such as issuing a conditional pass for heavy duty vehicles and increased lockouts for situations such as failing to meet insurance requirements. A new streamlined suspension/termination procedure has also been implemented to support the guideline.

The enhanced Compliance Guideline contains an expanded remedy schedule, more severe consequences for some infractions and an expanded authority for the QA/QC contractor to impose immediate lockouts. The remedies escalate if non-compliance infractions reoccur a second or third time. The escalating remedy schedule is expanded from eight examples of non-compliance events and associated remedies to fifty-eight examples. Examples of increases to suspension periods are as follows; refusing to allow auditor access to facility – first time event suspension increased from 3 months to 6 months; test only facility conducting emissions repairs – first time event increased from 3 months to 6 months, and; falsifying test records (clean piping) – first time event suspension increased from 6 months to termination of accreditation. Lockout infractions include additional examples such as failure to follow relocation protocols, failure to keep inspector password confidential and certified inspector not on site.

Tables 5-14 and 5-15 show the number and distribution of audits of light-duty DCFs conducted each year, by type of audit. At the beginning of the program nearly half (45%) of the audits conducted were for initial DCF certification; in 2004 less than 3% of audits conducted were for initial DCF certification. While roughly the same number of covert and overt audits were conducted in the first year (each 26% of all audits), in 2004 more overt audits (51% of all audits) were conducted than covert audits (32% of all).

Table 5-14. Number of Light-Duty DCF Audits Conducted Each Year, by Audit Type

	Year					
Audit type	1999	2000	2001	2002	2003	2004
5-gas revisit	77	227	359	208	462	572
Covert	840	1,272	1,740	1,926	1,730	1,743
Overt	854	1,272	2,569	3,098	2,736	2,783
Initial	1,424	637	484	651	170	139
Other	4	73	88	362	148	268
Total	3,199	3,481	5,240	6,245	5,246	5,505

Table 5-15. Percent Distribution of Light-Duty DCF Audits Conducted Each Year, by Audit Type

	Year					
Audit type	1999	2000	2001	2002	2003	2004
5-gas revisit	2.4%	6.5%	6.9%	3.3%	8.8%	10.4%
Covert	26.3%	36.5%	33.2%	30.8%	33.0%	31.7%
Overt	26.7%	36.5%	49.0%	49.6%	52.2%	50.6%
Initial	44.5%	18.3%	9.2%	10.4%	3.2%	2.5%
Other	0.1%	2.1%	1.7%	5.8%	2.8%	4.9%
Total	100%	100%	100%	100%	100%	100%

Note: Covert audits include full and focused covert audits; other covert audits are of the DCF visual audits; other includes educational, referee, OTU relocation or replacement, OTU closeout or withdrawal, and change in DCF type audits.

Tables 5-16 and 5-17 show the number and distribution of audits of heavy-duty DCFs conducted each year, by type of audit. Most audits of heavy-duty DCFs are conducted over the telephone; the number of phone audits increased dramatically in 2004.

Table 5-16. Number of Heavy-Duty DCF Audits Conducted Each Year, by Audit Type

	Year					
Audit type	1999	2000	2001	2002	2003	2004
Initial	465	221	28	20	30	32
Telephone	0	9	11	6	10	1,066
Field	0	876	683	651	578	477
Other	0	0	2	3	7	20
Total	465	1,106	724	680	625	1,595

Table 5-17. Percent Distribution of Heavy-Duty DCF Audits Conducted Each Year, by Audit Type

	Year					
Audit type	1999	2000	2001	2002	2003	2004
Initial	100.0%	20.0%	3.9%	2.9%	4.8%	2.0%
Telephone	0.0%	0.8%	1.5%	0.9%	1.6%	66.8%
Field	0.0%	79.2%	94.3%	95.7%	92.5%	29.9%
Other	0.0%	0.0%	0.3%	0.4%	1.1%	1.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Other includes OTU replacement, OTU closeout or withdrawal, and referee test audits.

Table 5-18 shows the number of DCFs and the number of overt, covert and telephone audits budgeted to be performed each year, by DCF type. The table shows the anticipated and actual number of DCFs of each type, and the number of audits to be performed each year per

DCF. Note that, for light-duty DCFs, on average 3.5 audits are performed per test-only DCF, and 2.5 audits are performed per test-and-repair DCF.

Table 5-18. Number of DCFs and Audits Scheduled, by DCF Type and Audit Type, Data as of February 2005

	Light-duty			Heavy-duty
Audit budgets	Test-and-repair	Test-only	Repair-only	Test-only
Actual number of DCFs	1,405	60	233	634
Estimated number of DCFs	1,500	55	300	630
Overt audits per year	2,250	83	450	465
Covert audits per year	1,500	110	112	
Telephone audits per year				780
Total audits per year	3,750	193	562	1,245
Audits per actual DCF	2.7	3.2	2.4	2.0
Audits per estimated DCF	2.5	3.5	1.9	2.0

Table 5-19 shows the number of audits and remedies levied by the DCO, by type of remedy and year. The table indicates that, since the start of the program, the number of in performance interviews and correction notices has decreased, while the number of audits conducted and lockouts has increased. These changes occurred prior to the adoption of the risk and performance based audit trigger system.

5.4.1.2 Risk and Performance Based Audit System

The analysis of performance indicators that trigger an audit was automated and updated January 1, 2003 (risk and performance based audit system). This new risk and performance based audit system gives DCO more flexibility in allocating audit resources towards DCFs that are more likely to be non-compliant. The system uses “filters” or “triggers” to automatically analyze data from every emissions test, as well as complaint data and auditing data to prioritize incidents of potential non-compliance, for the purpose of scheduling further follow-up auditing activity. The system uses 18 triggers for the light duty program and 8 triggers for the heavy-duty program.

The risk and performance based audit system compiles data that allows DCO to evaluate the system’s effectiveness. The knowledge-based compliance tool automatically identifies and measures the effectiveness of the triggers for targeting non-compliant DCFs. This allows program managers to use success indicators to modify system design for increased effectiveness and efficiencies of compliance efforts. ERG was not able to assess this feature.

Table 5-19. Number of Remedies by Type of Remedy, Vehicle Type, and Year

Remedy	1999	2000	2001	2002	2003	2004	2005[2]	Total
Audits[1]								
Light-duty	3,199	3,481	5,240	6,245	5,246	5,505	2,260	31,176
Heavy-duty	465	1,106	724	680	625	1,595	604	5,799
Correction notices								
Light-duty	2,377	3,163	4,744	1,863	1,060	1,436	144	14,787
Heavy-duty	0	631	493	477	308	477	150	2,536
Performance interviews								
In-person	34	48	51	24	41	27	2	227
Light-duty phone	0	3	105	141	0	0	0	249
Heavy-duty phone	0	1	0	0	0	0	0	1
Group	0	0	87	0	0	0	0	87
Total	34	52	243	165	41	1	0	536
Lockouts								
Light-duty	2,611	3,282	2,850	4,325	4,458	4,367	2,348	24,241
Heavy-duty	572	370	381	497	597	603	278	3,298
Suspensions	6	19	20	22	27	28	106	228
Withdrawals	1	2	24	27	38	56	31	179
Terminations	0	0	3	14	17	23	9	66

[1] There were approximately 100 additional initial audits performed in 1998.
[2] As of May 2005.

The current system allows different weights to be applied to different triggers; this capability can be used to fine-tune the system to give greater weight to some triggers that may have a high probability of being indicators of test fraud as opposed to those that may be less serious. However, all but one trigger currently receive the same weight in ranking DCFs subject to audit.

DCO currently uses a series of indicators to trigger an audit of a DCF; the type of audit depends on which triggers the DCF "tripped". It is outside the scope of this project to examine all of these triggers in detail. However, we analyzed the rates by phase and year of three triggers to assess whether the enforcement program has been effective in reducing these types of non-compliance and potential test fraud over time. Our analysis of these three triggers found that one of the indicators of non-compliance has been reduced, particularly since the risk and performance based audit system was adopted in January 2003.

The best approach to evaluate the effectiveness of specific triggers is to analyze the distribution of audits, and compare the fraction of audits that result in DCF suspensions or terminations, by the specific indicators that triggered the audit. This will allow DCO to assess which indicators are triggering audits and resulting in DCF suspensions or terminations. DCO can then either remove ineffective indicators or assign higher weights to effective indicators to

make the system more efficient (i.e. allocate audit resources to DCFs that will generate DCF suspensions and/or terminations). This is not a simple analysis, since audits are scheduled based on the results of the analysis of multiple triggers.

5.4.2. Registration Fraud

Registration fraud refers to registration renewals and ownership transfers that are completed without valid *Drive Clean* test "passes". This occurs when the electronic verification of the test on the *Drive Clean* database cannot be completed and a manual transaction using a certificate that appears legitimate is permitted as a customer service. Historically, the certificate number could be cut from the paper report generated after a passing I/M test, and pasted or used as a template to create a fake paper certificate for a vehicle that was likely to fail its emissions test. This "cut and paste" duplicate could then be used to transfer a vehicle or renew its registration at an MTO Issuing Office. The clerk at the MTO facility would run the vehicle registration number and find that there had been no electronic receipt of a passing emissions inspection for the vehicle. The individual requesting the transfer or renewal would then produce the illegitimate paper certificate to the clerk who would process the registration transaction using the certificate number from the illegitimate certificate.

In response to this issue, the DCO reported to the Office of the Provincial Auditor of Ontario that a substantial number of paper emissions certificates with a single certificate number had been used to register more than one vehicle (a fact which was reflected in the Office of the Provincial Auditor's 2004 report). The Ministry of Environment and Ministry of Transportation also implemented procedures to prevent the acceptance of invalid paper passes - the most recent being a registration system change made between July 2004 and December 2004 to permit only one paper use of a certificate number (and to confirm the validity of the VICN). After this change was made, analysis performed by the DCO showed the number of certificates used to manually renew registration of 6 or more unique vehicles decreased from approximately 2,500 per month in June 2004 to less than 10 per month after June 2004.

At this time it remains necessary to allow one paper use of a certificate number for registration, as there are a variety of reasons that the test may not be available for electronic verification at the time of the transaction. These include computer communication times, manual business processes, and manual data entry issues. Unfortunately, only electronically verified tests are known to be real, and this one paper use continues to be subject to fraud. Between January 1, 2005 and June 14, 2005, there were 1,490,018 *Drive Clean* registration transactions. Of these, 94,218 or 6.3% were manual transactions, and 5,549 or 5.89% appear to be fraudulent.

The potentially fraudulent transactions represent 0.37% of all *Drive Clean* registration transactions for this period.

The two ministries are currently working on further operational changes and security measures for paper passes to be implemented in 2005. They are also taking steps to increase the percentage of tests that are available for Issuing Office transactions within the 30 minutes of the test (current DCO information indicates that over 30% of owners obtain their test on the day they complete their transaction and of these 70% need to use manuals), to keep the need for paper transactions to the absolute minimum.

For day-to-day tracking and reporting fraudulent use of paper certificates, the program has access to an MTO registration transaction audit file that can be queried for identification of fraudulent manual uses, and the IS Contractor has established an interactive web application (MTO-VETS Reconciliation System) that allows comparison of valid certificate numbers issued by DCFs to specific vehicles with certificate numbers used for specific vehicles at MTO offices.

As of June 2005, the OPP and IEB have worked together to investigate fraudulent activities related to *Drive Clean* pass certificates.

Analysis of Historical Registration Fraud

ERG compared the VINs and VICNs in the emission test result database with those in the MTO registration transaction database, to assess the extent of three kinds of registration fraud over time:

- no-final-pass vehicles in the emission test database that renewed their registration in the transactions database with a VICN generated by a different vehicle;
- VICNs used to renew the registration of more than one vehicle;
- superceded VICNs generated by one vehicle to renew the registration of another vehicle.

Our analysis of historical registration fraud indicates that DCO has been responsive to incidents of registration fraud, and worked to close loopholes in the process that allow motorists to engage in such fraud. However, our experience with fraud in other programs indicates that a small segment of motorists are persistent in identifying and taking advantage of loopholes in the system. DCO should be vigilant in identifying new methods of registration fraud, and making changes in the program that minimize the number of registration renewals that do not meet program requirements.

5.4.3 On-Road Enforcement

The *Drive Clean* program is complemented by Ontario's Vehicle Emissions Enforcement Unit (VEEU) also referred to as the Smog Patrol. This program provides on-road inspection of vehicles suspected of emitting excessive exhaust smoke or of having emissions control equipment that has been tampered with or removed. The program uses a risk-based approach in order to focus inspections on specific transportation sectors that present the greatest risk to air quality. Vehicles that meet the criteria for specific sectors are targeted based on observations made by the officer. These may include signs of tampering with emissions controls, lack of maintenance, strong odors or visible emissions. These vehicles are pulled over for a mandatory inspection. The VEEU conducts inspections throughout the province but focuses its efforts mainly in the *Drive Clean* program area.

The inspections consist of a visual inspection of tampered or missing emission controls, and a snap opacity test for heavy-duty diesel vehicles. If the vehicle fails the Smog Patrol inspection, its operator can be issued a Form 1 order, a Provincial Officer Order, a Part 1 ticket, or a Part 1 summons, at the discretion of the Environmental Officer conducting the inspection. A Form 1 order requires that the vehicle be inspected at a *Drive Clean* facility or at the DCO-run Vehicle Emissions Centre (VEC) within a specified time period (at the discretion of the Environmental Officer). If the vehicle does not report for testing within the specified time period, the owner may be subject to a $425 fine. Vehicles that fail the inspection at the VEC are not required to be repaired unless a Provincial Officer Order is issued. Currently it is up to the Environmental Officer to ensure that vehicles receiving a Form 1 order report for testing at the VEC. Typically the officer requests that the vehicle owner fax the emissions test result to the officer. A Part 1 ticket requires that the vehicle owner pay a fine ($305 for light-duty vehicles, $425 for heavy-duty vehicles); however, there is no requirement that the vehicle be tested or repaired. A Part 1 summons similarly involves a fine, but also requires that the vehicle owner report to a court, where the residing judicial officer can increase the fine levied. Part 1 summons are usually issued for repeat offenders or for significant violations. However, as with the Part 1 ticket, there is no requirement that the vehicle be tested or repaired. Light-duty vehicles registered outside of the *Drive* Clean program area are inspected for tampering and visible emissions. Form 1 orders are not issued for vehicles registered outside of the *Drive Clean* program area; however these vehicle owners can be ticketed or ordered to repair their vehicles.

Recently Smog Patrol implemented the use of Provincial Officer Orders, which can be issued to individuals or companies and can require that a vehicle be repaired, or its use restricted until it meets emission standards. The Provincial Officer Orders require that repairs to reduce

emissions are documented and submitted before the order is lifted. Such orders can be issued to any vehicle driving in the *Drive Clean* program area, including those registered outside of the program area Environmental Officers also have the authority to seize vehicle license plates and ownership permits.

In December 2004 the number of Smog Patrol officers was reduced from 24 to 12 and an assessment of how to better target Smog Patrol inspections to suspected high-emitter vehicles was made. The VEEU is in the process of implementing a Computer Assisted Mobile Enforcement Office (CAMEO), which will allow officers to enter inspection data and issue tickets, summonses, and orders at the roadside immediately after the Smog Patrol inspection. The CAMEO enhancements will also facilitate the tracking of vehicles cited by Smog Patrol officers, and remind them to follow-up on citations and orders which have not been addressed by the vehicle owner.

Very few jurisdictions use on-road testing to identify high emitting light-duty vehicles for off-cycle I/M testing. California conducts roadside pullover ASM tests on approximately 2,000 vehicles per year; however, although motorists are required to pull their vehicle over when flagged by a highway patrolman, they can decline to submit their vehicle to a roadside visual or emissions inspection. California uses the roadside pullover data only for program evaluation purposes.

Table 5-20 summarizes heavy-duty diesel roadside testing programs in other jurisdictions. 13 jurisdictions other than Ontario have ongoing programs to randomly flag heavy-duty diesels for roadside emissions testing. Fines for first citations range from CDN$126 (US$100) in New Hampshire to CDN$1,260 (US$1,000) in Maryland; the fine for a first time citation in Ontario is CDN$500 (US$397).

Table 5-20. Roadside Heavy-Duty Diesel Vehicle Opacity Testing Programs

State	Start Date	Model Years	Test Procedure	HD Fines: 1st citation/ 2nd in 1 yr	Cutpoints (percent opacity)
AZ (Phoenix)	(pilot)	1967+	J1667		67-90: 55%; 91+: 40%
CA	1998		J1667	$800/$1800	<90: 55%; 91+: 40%
CT	1998	All	J1667	$300/$500	<74: 70%; 74-90: 55%; 91+: 40%
ID			Snap idle		65-74: 70%; 75-91: 55%; 92+: 40%
IL	1992		Snap idle	$400/$1000	<74: 70%; 74-90: 55%; 91+: 40%
ME			Snap idle	$250/$575	<74: 70%; 74-90: 55%; 91+: 40%
MD	1993	All	J1667	$1000/$1000	<74: 70%; 74-90: 55%; 91+: 40%
NV	1996	All		$800/$1500	All: 70%
NH			Snap idle	$100/$500	<74: 70%; 74-90: 55%; 91+: 40%
NJ	1997	All	J1667	$350/$700	<74: 70%; 74-90: 55%; 91+: 40%
NY	1999	All	Snap idle	$700/$1300	<74: 70%; 74-90: 55%; 91+: 40%
PA	1999 Pilot				Never implemented
VT		All	Snap idle		<91: 55%; 91+: 40%
WA	1993	1968+	J1667		68-73: 70%; 74-91: 60%; 92+: 40%
BC	1999		J1667		<91: 55%; 91+: 40%
ONT	2000		J1667	Up to $500/See note**	<91: 40%; 91+: 30% All school buses regardless of age: 30%

** Vehicles cited for a second citation within one year would be issued an additional ticket or summons, a Provincial Officer Order and/or would have their license plates seized. A second citation may result in a fine of $500.

Table 5-21 shows the number of vehicles inspected, and Part 1 tickets and summons issued, by fiscal year and vehicle type, by Smog Patrol. The program has inspected over 37,000 vehicles and issued charges against over 6,000 of them (17%). Data on the number of tickets and Part 1 summons are not available prior to fiscal year 2003. The bottom of Table 5-21 shows that 10% to 15% of inspected vehicles received a ticket from a Smog Patrol officer. While the percent of inspected light-duty vehicles that were ticketed was fairly constant over FY03 through FY05, the percent of inspected heavy-duty vehicles that were ticketed decreased from 23% in FY03 to 9% in FY05. Similarly, the percent of all inspected vehicles receiving a Part 1 summons decreased from 5% in FY03 to less than 1% in FY05, and the percent receiving a charge of any type decreased from 19% to 11%. It should be noted that the fiscal year 05 data were not complete at the time the information was provided.

Table 5-21. Smog Patrol Statistics – Inspections, Part 1 Tickets, Summons

	Inspections			Part 1 tickets			Part 1	All
Fiscal year	LD	HD	Total	LD	HD	Total	summons	charges
1998-99	NA	NA	725	NA	NA	NA	NA	130
1999-00	567	3,100	3,667	NA	NA	NA	NA	526
2000-01	3,425	769	4,194	NA	NA	NA	NA	654
2001-02	4,459	232	4,691	NA	NA	NA	NA	906
2002-03	6,803	176	6,979	939	41	980	360	1,340
2003-04	9,048	1,192	10,240	1,521	207	1,728	187	1,915
2004-05	5,609	1,297	6,906	589	121	710	48	758
Total	29,911	6,766	37,402	3,049	369	3,418	595	6,229
	80%	18%		89%	11%			
Percent of inspections								
1998-99				NA	NA	NA	NA	17.9%
1999-00				NA	NA	NA	NA	14.3%
2000-01				NA	NA	NA	NA	15.6%
2001-02				NA	NA	NA	NA	19.3%
2002-03				13.8%	23.3%	14.0%	5.2%	19.2%
2003-04				16.8%	17.4%	16.9%	1.8%	18.7%
2004-05				10.5%	9.3%	10.3%	0.7%	11.0%
Total				NA	NA	NA	NA	16.7%

In order to assess the effectiveness of the Smog Patrol program, it is necessary to have a complete list of VINs for vehicles inspected by Smog Patrol. This information was in the process of being compiled electronically by the ministry and was not available during the preparation of this report. At a minimum, all vehicles inspected by the Smog Patrol in the future should be identified, and matched with their emissions test results, to determine how many are following program requirements. Vehicles that are inspected but not cited should also be tracked, so that the effectiveness of the Smog Patrol in targeting suspected high emitters can be evaluated.

The Smog Patrol data can also be valuable in assessing certain aspects of the *Drive Clean* program. For instance, Smog Patrol can provide information on the fraction of no-final-pass vehicles that continue to be driven on Ontario roads without having passed their last I/M test.

The *Drive Clean* program is one of the few I/M programs in North America that uses unscheduled inspections of on-road vehicles to increase motorist compliance with program requirements. One of the strengths of *Drive Clean* is the existing Smog Patrol. However, data were not available to assess how effective the Smog Patrol is in encouraging motorists to comply with program requirements. We are not aware of any efforts to assess the effectiveness of unscheduled roadside testing in other jurisdictions. At a minimum, the vehicles that are pulled

over and tested can be tracked in the emission test result database to determine if they report for an off-cycle *Drive Clean* test, if required, or if they fail their next regular *Drive Clean* test. A survey of motorists and/or heavy-duty diesel vehicle operators could also be conducted, to determine whether they are aware of Smog Patrol activities and whether those activities have affected their vehicle maintenance practices. Arizona recently conducted telephone surveys and in-person focus groups to assess motorist knowledge of and attitudes toward the light-duty I/M program.

5.4.4 Investigations Function

Suspected violations of the Environmental Protection Act are investigated separately by the Ministry of the Environment's Investigations and Enforcement Branch (IEB). The IEB formed the *Drive Clean* Investigations Unit in November 2002, with a complement of four investigators. Prior to this, investigations were undertaken by Smog Patrol officers working as Special Project Officers reporting to IEB.

The *Drive Clean* Office, Ministry of Transportation (MTO) Offices, the Smog Patrol and local police forces can all refer DCFs conducting suspicious activities to IEB for legal investigations. IEB also investigates specific cases involving the potentially fraudulent issuance or use of illegitimate certificates, primarily as a result of vehicle clean-piping or using a cut-and-paste method to create illegitimate paper certificates (as described in Section 5.4.2). As described above, clean-piping refers to deliberately testing a known clean vehicle in order to generate a fraudulent certificate for another, suspected high-emitting vehicle.

Table 5-22 shows the number of investigations opened, convictions, and investigations closed without conviction, by fiscal year.

Table 5-22. Number of Investigations Opened, Convictions, and Investigations Closed Without Conviction, by Fiscal Year, as of February 17, 2005

Activity	2000-01	2001-02	2002-03	2003-04	2004-05	Total
Investigations						
Clean-piping	11	4	8	19	3	45
Cut-and-paste	1	17	30	122	71	241
Other	1	4	14	19	13	51
Total investigations	13	25	52	160	87	337
Convictions						
Clean-piping	3	3	0	4	9	19
Cut-and-paste	0	0	2	6	8	16
Other	0	0	3	0	1	4
Total convictions	3	3	5	10	18	39
Closed no convictions	3	3	29	40	27	82
Total fines	$13,000	$35,750	$11,000	$52,750	$86,300	$198,800

As of February 17, 2005 there were 200 open investigations assigned, of which 159 related to cut-and-paste certificates. There is a 2-year statute of limitations on cases. There were 8 cases before the courts; 5 for cut-and-paste certificates and 3 for clean-piping. There were 4 investigations prior to fiscal 2000/2001 for which the disposition has been counted.

5.5 Public Acceptance

Public acceptance is an important performance objective for the *Drive Clean* program. The most recent polling information available for the program is from an Environics Research poll conducted in July 2000, which found an 80 per cent approval rating for the program. ERG did not review the methodology or results of this poll, and cannot comment on how representative it is of public opinion regarding the program.

In the absence of any recent polling data, it is difficult to assess the current public acceptance of the program. One indicator of public acceptance or satisfaction with the program is the number of customer complaints about the program and disputes resulting from a test and/or repair experience.

All motorist complaints are initially lodged through the program's 1-800 Call Centre run by a private contractor, whose staff assist customers with their questions, concerns, and any complaints or disputes with a test and/or repair experience. A complaint is defined as any notification of disapproval by the industry or the general public, of any aspect of the *Drive Clean* program.. A dispute is defined as any notification of an unsatisfactory test and/or repair experience involving a *Drive Clean* facility that requires the intervention of the Call Centre

contractor, the Quality Assurance/Quality Control (QA/QC) contractor, or the DCO, between the customer and the DCF.

The *Drive Clean* Office has implemented an Integrated Complaint Management System (ICMS) that records and tracks customer disputes regarding an unsatisfactory test and/or repair experience at a DCF. The ICMS was implemented to improve the efficiency of the complaint management process with the objectives of enhancing the program's customer service delivery by providing one-window customer service, and ensuring a transparency and accountability in the handling of customer complaints and disputes.

There is a three level public complaint/dispute resolution process that is in use by *Drive Clean* and is tracked by the ICMS. The first level involves intervention by the Call Centre contractor with the complainant and the DCF. A level 2 dispute involves intervention by the QA/QC contractor with the complainant and the DCF. A level 3 dispute involves intervention by the DCO with the complainant and the DCF.

Table 5-23 shows the average number of calls to the Call Centre per month for 2003 and 2004, and includes the average number of complaints and disputes per month. Between 2003 and 2004, the average number of calls to the Call Centre decreased by approximately 1,000 calls per month. The average number of monthly program complaints increased from 172 complaints per month in 2003 to 196 complaints per month in 2004. The average number of test and/or repair disputes per month decreased from 59 in 2003 to 34 in 2004.

Table 5-23. Average Number of Monthly Public Inquiries, Complaints and Disputes to the *Drive Clean* Call Centre for 2003 and 2004

Year	Average Tests per Month (LDV)	Average Call Centre Calls per Month	Average Monthly Program Complaints	Average Monthly Test and/or Repair Disputes	Average Total Complaints and Disputes
2003	209,000	16,700	172	59	231
2004	257,000	15,700	196	34	230

As a ratio of the average number of tests conducted monthly, less than 1 in every 5,000 *Drive Clean* tests performed resulted in a test and/or repair dispute in 2003 and in 2004. Less than 1 in every 1,000 *Drive Clean* tests performed resulted in a program complaint for both 2003 and 2004. As an indicator of public acceptance or satisfaction with the program, the number of

complaints and test and/or repair disputes is small in relation to the number of emissions tests conducted in the program.

5.6 Revenue Neutrality

The *Drive Clean* program is funded entirely by a portion of the test fees charged to motorists for *Drive Clean* tests. When the program started, the fee for an initial test of a light-duty vehicle was CDN$30, while the fee for a retest was CDN$15. DCFs submit one-third of the fee for each passing test (CDN$10), and two-thirds for each passing retest (CDN$10), to DCO. In October 2002 the light-duty test fees were increased, to CDN$35 for an initial test and CDN$17.50 for a retest, with the portion submitted to DCO increasing to CDN$11.67. This fee increase was instituted to fund an enhanced Smog Patrol and conduct on-road enforcement of the program. DCO also receives CDN$15 per passing heavy-duty vehicle test (the heavy-duty test is determined by the market; the current average fee is reported to be CDN$75). Ontario government approval for the *Drive Clean* program stipulates that total *Drive Clean* expenditures over the life of the program will equal the total revenue collected, so that the program is revenue-neutral.

Table 5-24 shows the actual and projected costs and revenues of the Drive Clean program, by fiscal year (the Ontario fiscal year runs from April to March). Projected costs and revenues are shown in italics in the table. According to DCO's internal numbers and projections, the program will be revenue neutral in fiscal year 2006-07.

Table 5-24. Actual and Projected Government Costs and Revenues, in Thousands of Dollars (Canadian), by Fiscal Year

	Fiscal year ending	Costs	Revenue	Break-even (Net Present Value)
Actual	1998	$940	$0	-$888
	1999	$17,500	$745	-$16,709
	2000	$26,200	$15,670	-$26,099
	2001	$23,100	$18,370	-$30,081
	2002	$22,900	$24,075	-$29,147
	2003	$22,400	$30,599	-$22,991
Projected	*2004*	*$26,366*	*$33,782*	*-$17,733*
	2005	*$24,177*	*$34,516*	*-$10,812*
	2006	*$22,529*	*$35,470*	*-$2,631*
	2007	*$22,489*	*$36,105*	*$5,497*
	Total	$208,601	$229,332	

Other programs rely on sources of revenue other than test fees to finance their operations. For example, the Colorado program receives only US$0.25 of the US$25 test fee for every test

conducted (the centralized test contractor receives the remaining US$24.75); this revenue has to be spent on the I/M program. However, the state Department of Public Health and Environment also receives US$1.50 of the registration renewal fee for vehicles in the I/M area, US$0.30 of renewal fee for vehicles outside of the I/M area, and US$10 of the renewal fee for diesel vehicles, which can also be spent on the I/M program, as well as other policies to improve local and regional air quality.

6.0 Assessment of Future Options for LDV and HDV Programs

6.1 Identification of Options and Evaluation Criteria

In the current evaluation of the program the ERG team considered many new approaches to improve the effectiveness of the program, evaluating potential emissions reductions, cost effectiveness, social and other impacts of the program.

The *Drive Clean* process has four discrete, functional components, each of which is critical to the overall success of any I/M program. These components include:

- Identification of high emitters
- Performing effective and durable repairs on failing vehicles
- Motorist and DCF compliance
- Enforcement

The evaluation of options for the *Drive Clean* program considered impacts on each of these components, with respect to financial impacts, convenience, and environmental and social concerns.

At the start of this analysis ERG reviewed other I/M programs around the US and Canada, identifying the most effective strategies for each of the four I/M program components listed above. Options selected for this analysis were restricted to measures that have already been successfully adopted in other programs, or could be carefully evaluated using existing information. For many options, several alternatives are included in this section. For completeness, these alternatives aren't limited to those we felt were most viable. Rather, advantages and disadvantages are presented for all options, and recommendations of the options we feel are the best candidates are provided in this section and summarized in Section 7.

Next, ERG evaluated existing information for the *Drive Clean* program by analyzing more than five years worth of emissions test data collected under the program. This process helped us identify specific features of the current program that could be enhanced. Measures that would require "proof of concept" demonstrations or further evaluations to assess their technical feasibility were usually excluded from further consideration. The development of options also considered the characteristics of the future vehicle fleet in Ontario.

When sufficient information was available, either through actual performance evaluations or modeling, quantitative evaluations were performed to estimate mass emissions and/or costs

and cost-effectiveness for the options identified. In other cases more qualitative assessments were made of costs and benefits. While the incremental cost-effectiveness results presented for each option are instructive in assessing the potential value of future year operation and alternative program options, it should be noted that simplifying assumptions were made that may limit their utility. For example, all cost analyses assumes that the number of accredited DCFs per vehicle will stay approximately constant over time, regardless of any changes in test and repair costs or revenue streams entailed by the option itself. (Obviously if revenue streams fell enough, some number of DCFs would start to leave the market.) Similarly ERG assumed that tailpipe fail rates would remain constant at their 2003-2004 level, although these rates have been consistently trending downward since the start of the program.[30] While this study did not include a macroeconomic assessment of service sector shifts as a function of cost and revenue changes, we acknowledge these impacts could be real and significant.[31]

It should also be noted that the cost-effectiveness estimates presented for each option are all relative to the current program baseline. If more than one of these alternatives is selected, the cost-effectiveness for the resulting cost-effectiveness of the entire package of options may not be equal to the sum of these individual estimates. Therefore the cost-effectiveness of any future program modifications will depend on the specific bundle of options that are selected by the Ministry.

In addition to emission reductions and costs, each option was evaluated in terms of several discrete evaluation criteria, relative to the current *Drive Clean* program. Each criterion is described briefly below.

- *Environmental Impact* – This criterion is tied directly to the emission reduction potential of each option. Differential impacts on the ozone precursors (VOC and NOx), particulate matter (PM), and CO and CO_2 reductions were noted.
- *Health Impact* – This criterion is closely related to emission reductions. Options that preferentially reduce particulate matter emissions (including its precursors, sulphur dioxide and nitrogen oxides, which convert to fine particulates in the atmosphere) should be assigned greater weight than those focusing on ozone precursor emissions, to the extent that particulate matter impacts a wide range health issues including cancer, while impacts associated with ozone precursors may be less severe.

[30] ERG made this conservative assumption because explicit predictions of future fail rates are unavailable, and because ASM cutpoints were tightened at the start of 2005, which should tend to minimize – or possibly reverse - this effect.

[31] Another confounding factor includes the change in the remaining life of aging ASM test equipment resulting from increases or decreases in test volumes (e.g., significant decreases could result from OBD adoption, thereby extending dynamometer life.)

- *Financial Impacts* – Many of the options will require additional expenditures on the part of the motorist (e.g., for more extensive repairs or more frequent tests), the DCFs (e.g., for new testing equipment), or the DCO (e.g., for additional oversight of OBD testing). (Non-financial costs such as increased motorist wait times and health impacts are not explicitly evaluated under this criterion.) Certain options will also affect the revenue stream of the DCFs (e.g., changes in the number of tests per year, or changes in fail rates/repair revenue), which will in turn impact their overall financial situation. For this analysis ERG assumed test fees would remain unchanged, unless otherwise noted.
- *Cost Effectiveness* – ERG estimated the incremental costs and emissions reductions for each option relative to the current *Drive Clean* program, combining them to estimate dollars per tonne of emission reduction. When quantitative estimates were available, emission reductions were expressed in terms of VOC+NOx) to reflect typical ozone precursor weightings. Quantitative cost estimates are expressed in constant CDN$2005 when possible, and discounted at a standard rate in order to be consistent across measures. Note that most measures become less cost-effective over time due to cleaner baseline emissions, just as with the base case I/M program.
- *Social Impacts* – This criterion includes a number of qualitative components, including customer acceptance, consumer protection, and the overall equity of the option.
- *Program Impacts* – There are several points of special concern to the DCO that were evaluated for each measure. These include direct costs to the DCO needed to implement and oversee program changes, the impact on test fee revenue, and the logistical difficulty associated with the measure. For our analysis ERG assumed that, barring a change in the current test fee, increased passing test volumes would result in increased test fee revenue, while decreased passing test volumes would result in decreased test fee revenue. Program Logistics is a qualitative assessment of the impact of the change on program administration (how much effort will the option require to implement and maintain). All options will impact future net cost-effectiveness, and this will need to be assessed by the ministry.
- *Compliance Impact* – ERG attempted to assess whether the different options would tend to encourage or discourage vehicle owner and DCF compliance with *Drive Clean* requirements, relative to the current program.

The options identified through our review of other programs and of existing *Drive Clean* data fall into several categories: incremental program changes which are adjustments to the current program (e.g., modifying the model year exemption period); addition of new testing technologies or methods (e.g., use of On-Board Diagnostic system checks); expanded or modified use of existing *Drive Clean* program components (e.g., greater use of Smog Patrol

testing), and; adoption of other new program features (e.g., a low income repair assistance program.) A complete list of the options evaluated in this report is provided below:

Incremental Program Changes

- Expanded model year exemptions for newer vehicles
- Extending program coverage to older model year vehicles
- Requiring off-cycle emissions tests for vehicles that failed the previous year
- Requiring annual testing for high-use and/or high-emitting vehicles
- Extended uniform vehicle preconditioning
- Cutpoint modifications
- Restricting the issuance of conditional passes
- Adjust repair cost limit

New Testing Technologies and Procedures

- Implementation of OBDII (with and without ASM tests)
- ASM testing for light-duty diesels
- ASM testing for heavy-duty gasoline vehicles
- Evaporative test for gross liquid leakers
- Computer reflash for heavy-duty diesel vehicles
- OBD checks for heavy-duty vehicles
- Targeting high-emitters using remote sensing devices (RSD)

Expanded Use of Existing Program Components

- Enhanced targeting high-emitters through use of Smog Patrol
- Enhanced utilization of the Vehicle Emissions Centre (VEC)
- Enhanced use of official test result data for repair effectiveness improvements
- Enhanced compliance and fraud prevention tools

New Program Features

- Low income repair assistance (LIRAP)
- Accelerated vehicle retirement
- Repair Effectiveness Index

Table 6-1 below summarizes the evaluation results for the different options included in the analysis. Symbols in the table indicate the following (impact of option relative to the existing program): "+" indicates a positive impact (benefit), "=" indicates a neutral impact (no significant impact expected), and a "-" indicates a negative impact benefit reduction). The "?" signs indicate uncertainties which require further evaluation. In Table 6-2, up or down arrows indicate an increase or decrease in the evaluation category. In Table 6-4, a "+"sign for net revenue indicates the change would result in additional program income. Similarly, a "-" sign indicates a net reduction in program income. An "=" sign indicates no change in net program income or expenditures. Tables 6-2 through 6-5 provide additional levels of detail regarding some of the evaluation criteria. The assessments summarized in these tables are described in the following sections.

Table 6-1. *Drive Clean* Options Analysis – Results by Major Criterion

	Environmental Impacts	Health Impacts	Financial Impacts	Cost Effectiveness	Social Impacts	Program Impacts	Compliance Impacts
Exempt 2 additional new Mys in LD Program	-	-	-	+	+	+	=
End 20 Year Exemption in LD Program	+	+	+	+	-	+	-
Require Annual Testing for Previous Initial Fails	+	+	-	+	-	?	-
Implement LDGV OBDII/ ASM testing	+	+	-	?	-	-	+
Ensure ASM Testing at Operating Temperature	=	=	+	+	+	+	=
Perform a LD Diesel Test Pilot Program	=	=	-	=	=	-	=
Target High Emitters - Smog Patrol	+	+	-	+	-	-	+
Target High Emitters - RSD	+	+	-	+	-	-	+
Limit # of Conditional Passes Granted	+	+	?	+	?	+	-
Increase RCL to Reduce Waivers	+	+	?	+	-	+	-
Implement a Vehicle Early Retirement Program	+	+	?	+	+	-	+
Low-Income Repair Assistance Program	+	+	?	+	+	-	+
Improve LD Repair Effectiveness	+	+	-	=	+	-	?
Establish a HD Chip Reflash Program	+	+	-	+	=	-	=
Monitor Effectiveness of HD OBDII Systems	=	=	-	=	=	-	=
Conduct Pilot Study on HD NOx and PM Testing	=	=	-	=	=	-	=
Prevent Test & Repair Fraud	+	+	-	+	+	-	+
Prevent Registration Fraud	+	+	-	+	+	-	+
Expand Use of VEC	=	=	-	?	+	-	=
Expand use of Smog Patrol	+	+	-	?	+	-	+
OVERALL	+	+	-	+	=	-	+
Require Annual Testing for Fleet Vehicles	+	+	-	+	-	-	-
Implement LDGV OBDII-only testing	+	+	-	?	+	-	+
Cut Point Modifications	+	+	-	?	-	+	-
Adopt Motorcycle Testing	+	+	-	+	-	-	-
Evaluate Evap Checks of Gross Liquid Leakers	+	+	-	?	=	-	=

Table 6-2. Expanded Detail – Financial Impacts

Financial Impacts				
	•DCF Financial Impact	•Program Financial Impact	•Motorist Financial Impact	
'	-	-	+	Exempt 2 additional new Mys in LD Program
+	+	+	'	End 20 Year Exemption in LD Program
'	+	=	'	Require Annual Testing for Previous Initial Fails
'	-	=	'	Implement LDGV OBDII/ ASM testing
+	=	=	+	Ensure ASM Testing at Operating Temperature
'	=	-	=	Perform a LD Diesel Test Pilot Program
'	+	-	'	Target High Emitters - Smog Patrol
'	+	-	'	Target High Emitters - RSD
?	+	=	'	Limit # of Conditional Passes Granted
?	+	=	'	Increase RCL to Reduce Waivers
?	-	-	+	Implement a Vehicle Early Retirement Program
?	+	-	+	Low-Income Repair Assistance Program
'	-	-	+	Improve LD Repair Effectiveness
'	'	=	=	Establish a HD Chip Reflash Program
'	=	-	=	Monitor Effectiveness of HD OBDII Systems
'	=	-	=	Conduct Pilot Study on HD NOx and PM Testing
'	+	-	=	Prevent Test & Repair Fraud
'	+	-	=	Prevent Registration Fraud
'	=	-	=	Expand Use of VEC
'	=	-	=	Expand use of Smog Patrol
'	+	'	'	OVERALL
'	+	-	'	Require Annual Testing for Fleet Vehicles
'	'	=	'	Implement LDGV OBDII-only testing
'	+	=	'	Cut Point Modifications
'	+	+	'	Adopt Motorcycle Testing
'	+	-	'	Evaluate Evap Checks of Gross Liquid Leakers

Table 6-3. Expanded Detail – Social Impacts

•Equity	•Consumer Protection	•Customer Acceptance	**Social Impacts**	
'	=	+	**+**	Exempt 2 additional new Mys in LD Program
'	=	'	**'**	End 20 Year Exemption in LD Program
=	+	'	**'**	Require Annual Testing for Previous Initial Fails
'	+	'	**'**	Implement LDGV OBDII/ ASM testing
+	+	+	**+**	Ensure ASM Testing at Operating Temperature
=	+	=	**=**	Perform a LD Diesel Test Pilot Program
'	=	'	**'**	Target High Emitters - Smog Patrol
'	+	'	**'**	Target High Emitters - RSD
+	'	'	**?**	Limit # of Conditional Passes Granted
+	'	'	**'**	Increase RCL to Reduce Waivers
+	+	+	**+**	Implement a Vehicle Early Retirement Program
+	=	+	**+**	Low-Income Repair Assistance Program
=	+	+	**+**	Improve LD Repair Effectiveness
=	=	=	**=**	Establish a HD Chip Reflash Program
=	+	=	**=**	Monitor Effectiveness of HD OBDII Systems
=	+	=	**=**	Conduct Pilot Study on HD NOx and PM Testing
+	+	+	**+**	Prevent Test & Repair Fraud
+	=	+	**+**	Prevent Registration Fraud
=	+	+	**+**	Expand Use of VEC
=	+	+	**+**	Expand use of Smog Patrol
+	+	'	**+**	OVERALL
'	=	'	**'**	Require Annual Testing for Fleet Vehicles
'	+	+	**+**	Implement LDGV OBDII-only testing
'	+	'	**'**	Cut Point Modifications
?	'	'	**'**	Adopt Motorcycle Testing
=	+	=	**=**	Evaluate Evap Checks of Gross Liquid Leakers

Table 6-4. Expanded Detail –Program Impacts

•Program Logistics	•Test Fee Revenue	Program Impacts	
+	-	+	Exempt 2 additional new Mys in LD Program
+	+	+	End 20 Year Exemption in LD Program
-	+	?	Require Annual Testing for Previous Initial Fails
-	0	-	Implement LDGV OBDII/ ASM testing
+	-	+	Ensure ASM Testing at Operating Temperature
-	0	-	Perform a LD Diesel Test Pilot Program
-	+	-	Target High Emitters - Smog Patrol
-	+	-	Target High Emitters - RSD
+	+	+	Limit # of Conditional Passes Granted
+	0	+	Increase RCL to Reduce Waivers
-	0	-	Implement a Vehicle Early Retirement Program
-	0	-	Low-Income Repair Assistance Program
-	0	-	Improve LD Repair Effectiveness
-	0	-	Establish a HD Chip Reflash Program
0	0	-	Monitor Effectiveness of HD OBDII Systems
-	0	-	Conduct Pilot Study on HD NOx and PM Testing
-	0	-	Prevent Test & Repair Fraud
-	+	-	Prevent Registration Fraud
-	0	-	Expand Use of VEC
-	+	-	Expand use of Smog Patrol
-	+	-	OVERALL
-	+	-	Require Annual Testing for Fleet Vehicles
+	0	-	Implement LDGV OBDII-only testing
0	+	+	Cut Point Modifications
-	+	-	Adopt Motorcycle Testing
-	0	-	Evaluate Evap Checks of Gross Liquid Leakers

Table 6-5. Expanded Detail – Environmental Impact

Environmental Impacts	-	+	+	+	=	=	+	+	+	+	+	+	+	=	=	+	+	=	+	+	+	+	+	+
VOC	-	+	+	+	=	=	+	+	+	+	+	+	+	=	=	+	+	=	+	+	+	+	+	+
CO	-	+	+	+	=	=	+	+	+	+	+	+		=	=	+	+	=	+	+	+	+	+	=
NOx	-	+	+	+	=	=	+	+	+	+	+	+	+	=	=	+	+	=	+	+	+	+	+	=
PM	=	=	=	=	=	=	+	=	=	=	=	=	+	=	=	=	=	=	+	=	=	=	+	=
	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL	Require Annual Testing for Fleet Vehicles	Implement LDGV OBDII-only testing	Cut Point Modifications	Adopt Motorcycle Testing	Evaluate Evap Checks of Gross Liquid Leakers

6.2 LDV Options Assessment

This section discusses options focusing on the light-duty portion of the *Drive Clean* fleet.

6.2.1 Exempt Two Additional New Vehicle Model Years (i.e., 4 and 5 year old vehicles)

6.2.1.1 Current Program

The *Drive Clean* Program currently exempts the three newest model year vehicles for registration renewal (i.e., the current year, 1 year old vehicles, and 2 year old vehicles are exempt from testing for registration renewal). Testing for resale starts for vehicles at one year of age.

6.2.1.2 Benchmark

Of the other jurisdictions evaluated, two exempt the five newest model years, nine exempt the four newest model years, and 16 exempt between one and three newest model years. Ten jurisdictions do not exempt any new vehicles from testing. The majority of I/M programs do not exempt more than the four newest model years in order to ensure that vehicles get at least one emissions test before the manufacturer's warranty expires.

6.2.1.3 Need for Change

Since a relatively large percentage of the fleet are newer vehicles, and these vehicles generally have lower emissions than older vehicles, increasing the exemption "window" could allow the number of emission tests administered annually to be reduced with a minimal loss of emissions benefit. This would make the program more cost-effective in reducing on-road emissions.

6.2.1.4 Analysis of Option

For this option, ERG considered increasing the number of new model year vehicles that would be exempt from testing for registration only.

Two scenarios were considered, exempting the five newest model years (so the current model year, 1-year old, 2-year old, 3-year old, and 4-year old vehicles would be exempt from testing for registration), and exempting the seven newest model years (exempting the current year up through 6-year old vehicles).

In consideration of the five model year exemption, the two newest model years that were eligible for testing in 2004 were 2000 and 2001 vehicles. Excluding these two additional model

years (increasing the exemption "window" to five model years) would have removed 22% of the subject fleet from the program, while reducing potential emission reductions by only 2% for HC, 3% for CO, and 4% for NO_x.

Increasing the exemption "window" up to 7 model years (exempting 1998 and newer vehicles in 2004) would remove 41% of the current fleet from the program, while reducing emission reductions by 6% for HC, 7% for CO, and 9% for NO_x.

Due to the small fleet percentage, and in order to protect owners of relatively new vehicles, the exemption for change of ownership vehicles was not evaluated as an option. This "test on resale" requirement allows newer resale vehicles to receive an emissions inspection before their manufacturer's emissions warranty expires.

Advantages

- Increasing the exemption "window" would allow the number of emission tests administered annually to be reduced with a minimal loss of emissions benefit.
- Removing four and 5-year-old vehicles from the program will improve program cost-effectiveness.
- Program costs (and motorist burden) will be reduced

Disadvantages

- Some emissions benefit (and consequently health benefits) will be lost by exempting additional model years
- Some consumer protection will be lost if vehicle malfunctions are not detected before manufacturer warranties expire
- DCF test fee revenue will be reduced

Table 6-6 presents emissions changes based on exempting the most recent fourth and fifth model years from testing, relative to just the most recent three vehicle model years.

Table 6-6. Emissions Changes from Increased Model Year Exemption (tonnes/yr)

Calendar Year	2005	2010	2015
NOx	-106	-88	-98
HC	-115	-137	-114
CO	-3,389	-2,715	-2,937
NOx+HC+CO/7	-705	-613	-632

The fraction of initial tests and failed tests that these model years represent was obtained from analysis of the *Drive Clean* test result database and combined to form a ratio for application to variable costs, such as consumables, labor, and repair parts. Table 6-7 summarizes the numbers of vehicles impacted and resulting emission reductions, while Table 6-8 presents the expected cost impacts to the DCFs, the Government, and to motorists. Finally, Table 6-9 presents the estimated cost effectiveness for this option. Note that adopting this option reduces the emissions benefits only by a small amount but generates significant cost reductions due to the large number of vehicles exempted, so this option improves the cost-effectiveness of the overall program.

Also note that this is one of the few options considered with important revenue neutrality impacts for the Government, possibly extending the timeframe for complete cost recovery. Similarly, this option would substantially decrease testing revenue to the DCFs.

Table 6-7. Impact of Option on Subject Fleet and Emission Reductions Exempt Years 4 & 5 -- 2005 Calendar Year

Model Year	# of Vehicles[32]	% of Fleet[33]	Failure Rate	Failing Vehicles	Emissions Reductions (Tonnes/Yr)		
					HC	CO	NOx
Base	2,292,222	37.8%	9.8%*	225,096	7,502	174,662	7,371
Exempt Yr 4 & 5	1,792,281	29.6%	12.3%**	219,997	7,388	171,273	7,265
Delta	*499,941*	*8.2%*	*1.02%***	*-5,099*	*-115*	*-3,389*	*-106*

* 2003 fail rate assumed

** ERG by-model year analysis, 4-year-old vehicles only

Table 6-8. Impact of Option on 2005 Costs & Revenues Exempt Years 4 & 5 (Millions of 2005 Canadian $/Yr)

	DCF Costs		Government Costs	Motorists Costs		Program Revenue	
	Fixed	Variable	Total	Tests	Repairs	To DCFs	To Gov't
Base Case	45.2	118.0	19.7	83.8	90.0	147.8	26.0
Exempt Years 4&5	45.2	106.9	19.7	66.2	88.0	134.1	20.1
Delta	*0*	*-11.1*	*0*	*-17.6*	*-2.0*	*-13.7*	*-5.9*

[32] DesRosiers Report.

[33] Derived from DesRosiers Report – 2005 test fleet as percentage of total fleet (all model years, all phases).

Table 6-9. Cost Effectiveness for Exempting Years 4 and 5 (2005 Canadian dollars/tonne HC+NOx+CO/7)

Calendar Year	2005	2010	2015
For testing model years 4 or 5 only in test year	$11,986	$15,510	$15,804
Modified I/M as a whole	$4,501	$5,241	$5,699

6.2.1.5 Recommendation

We recommend that *Drive Clean* consider exempting two additional model years (that is, exempting 5-year-old and newer vehicles, as opposed to the current 3-year-old and newer exemption). Exempting the first five model year vehicles would significantly reduce the number of *Drive Clean* tests required annually while having only a minimal reduction in *Drive Clean*'s emission reduction benefit. However, we do not recommend exempting an additional two model years (that is, 6 and 7 year old vehicles), as no other I/M program exempts so many model years, and exempting these vehicles from the program would have an unacceptable reduction in program emissions benefits. However, we recommend retaining *Drive Clean*'s existing "test on resale" requirement.

6.2.1.6 Impact of Recommendation

Exempting two additional model years from the program will greatly reduce program costs. These vehicles are about 3 to 4 times more costly to test and repair per tonne of reduction than the overall fleet average. These model years represent only a small portion of the overall emission reduction potential, and exempting them will result in a small reduction in emission benefits. However, this measure will result in a large reduction in DCF test fee revenue, and a small reduction in repair revenue. Similarly, test fee revenue for the program operations will be greatly reduced to both the DCO and DCF. For the DCO this would result in a delay in obtaining break-even on historical program expenditures to date.

A slight reduction in health benefits could be expected as a result of the slight reduction in emission benefits. Motorists, however, will benefit, as owners of these newer vehicles will not have to pay for and be inconvenienced by an emissions inspection that few will fail. Therefore this option should be popular with owners of these vehicles, although social equity could suffer as well-off owners of newer vehicles may be seen as getting preferential treatment. Average repair costs should not be affected by this option. This option should be relatively simple to implement.

6.2.2 End 20-Year Exemption for Older Vehicles (test 1981 and newer vehicles)

6.2.2.1 Current Program

Currently, the *Drive Clean* program has a rolling model year exemption for 20-year-old and older vehicles.

6.2.2.2 Benchmark

Eight other jurisdictions have a rolling model year exemption for older vehicles (with either 25- or 26-year-old and older vehicles exempted). Twenty-three jurisdictions exempt vehicles older than a specific model year (all but three of these test vehicles older than 1980), while three jurisdictions test vehicles of all ages.

6.2.2.3 Need for Change

Although relatively few of these vehicles are on the road today, and even though these vehicles are generally driven fewer kilometres than newer vehicles, these older vehicles still tend to pollute at much higher levels than newer vehicles and therefore represent the greatest emission reduction potential on a per-vehicle basis.

6.2.2.4 Analysis of Option

This option would involve ending the rolling-year exemption, and instead require all 1981 and newer vehicles to receive a *Drive Clean* test (in accordance with the biennial odd/even test cycle currently in place). 1981 was selected as the model year cutoff for this option because substantial emission control changes were introduced in U.S. vehicles in this year. Although equivalent standards were not adopted in Canada until 1987, we suspect there are numbers of U.S.-certified vehicles in this age range registered in the Ontario fleet that would benefit significantly from ASM testing.

Advantages

- Older vehicles still tend to pollute at much higher levels than newer vehicles. Including them in the program will improve cost effectiveness
- Eliminating the rolling model year exemption would slightly simplify test administration

Disadvantages

- Repairing older vehicles can be cost-prohibitive. Although these vehicles tend to pollute at higher levels, inclusion can be viewed by some as socially inequitable

- Benefits of ending the rolling window are reduced over time (as less of these older vehicles are on the roads)

Table 6-10 presents emissions reductions resulting from testing all model year vehicles from 1981 up to the current three year exemption, as opposed to the current system, which covers only the most recent three to nineteen years. This option would impact a large number of motorists unaffected by the current program, and would increase costs from both additional initial tests and a significant increase in retests for vehicle greater than 19 years old.

Table 6-10. Emissions Reductions from Testing 1981+ Vehicles (tonnes/yr)

Calendar Year	2005	2010	2015
NOx	1,282	914	357
HC	2,558	908	449
CO	39,515	17,249	9,302
NOx+HC+CO/7	9,485	4,287	2,135

1981 was selected as the model year cutoff for this option because substantial emission control changes were introduced in U.S. vehicles in this year. (Although equivalent standards were not adopted in Canada until 1987, we suspect there are numbers of U.S.-certified vehicles in this age range registered in the Ontario fleet that would benefit significantly from ASM testing and repairs).

An increase in failure rates for the overall fleet was derived from the percentage of the fleet older than twenty years (from the DesRosiers Report) and the average fail rates of those vehicles from analysis of the *Drive Clean* test results database. Impacts on vehicle numbers and emissions for 2005 are provided in Table 6-11. The failure rate increase was applied to variable costs, such as consumables, labor, and repair parts to obtain adjusted costs, which are presented in Table 6-12. Cost-effectiveness estimates are given in Table 6-13. Note that adopting this option increases emissions benefits by a relatively large amount, but only generates moderate cost increases due to the small number of vehicles added, so this option improves the cost-effectiveness of the overall program. Also note that the cost per tonne increases significantly from 2005 to 2015 as new car certification standards are continually reduced. Finally, we see that Government revenue impacts are relatively small, again due to the small number of vehicles added to the program. (The repair revenue increase to DCFs, while significant, is still not enough to offset the potential revenue loss associated with exempting year 4 and 5 vehicles however.)

Table 6-11. Impact of Option on Subject Fleet and Emission Reductions Test 1981 and Newer Vehicles 2005 Calendar Year

Model Year	# of Vehicles[34]	% of Fleet[35]	Failure Rate	Failing Vehicles	Emissions Reductions (Tonnes/Yr)		
					HC	CO	NOx
Base	2,292,222	37.8%	9.8%*	225,096	7,502	174,662	7,371
Option	2,311,655	38.2%	11.9%	273,937	10,061	214,177	8,653
Delta	*19,433*	*0.4%*	*53%***	*10,284*	*2,558*	*39,515*	*1,282*

* 2003 fail rate assumed
** ERG by-model year analysis, even model year vehicles

Table 6-12. Impact of Option on 2005 Costs & Revenues Test 1981 and Newer Vehicles (Millions of 2005 Canadian $/Yr)

	DCF Costs		Government Costs	Motorists Costs		Program Revenue	
	Fixed	Variable	Total	Tests	Repairs	To DCFs	To Gov't
Base Case	45.2	118.0	19.7	83.8	90.0	147.8	26.0
Test 81+	45.2	121.7	19.7	84.6	94.1	152.6	26.2
Delta	*0*	*3.7*	*0*	*0.8*	*4.1*	*4.8*	*0.2*

Table 6-13. Cost Effectiveness for Testing 1981+Vehicles (2005 Canadian dollars/tonne HC+NOx+CO/7)

Calendar Year	2005	2010	2015
For testing older than 19 years	$403	$1,114	$1,621
Modified I/M as a whole	$3,825	$4,954	$5,635

6.2.2.5 Recommendation

Based on the relatively large emission benefit available from including this small percentage of the fleet, we recommend ending the rolling-year exemption and testing all 1981 and newer vehicles (in accordance with the biennial odd/even test cycle current in place).

6.2.2.6 Impact of Recommendation

Ending the rolling model year exemption for older vehicles and including 1981 and newer vehicles in the program would increase emission reductions and improve cost-effectiveness, as the emission reduction per vehicle tested is much greater for older vehicles than newer vehicles. This recommendation will have a positive impact on health. The incremental

[34] DesRosiers Report.
[35] Derived from DesRosiers Report – 2005 test fleet as percentage of total fleet (all model years, all phases).

cost-effectiveness of including 1981 and newer vehicles in the current program is about $400 per tonne of HC+$NO_x$+CO/7, which is a factor of 10 times more cost-effective than the overall program. However, this option becomes less cost-effective with time, when there are very few of these older vehicles remaining on the road. Nevertheless, even in 2015 we estimate this portion of the fleet will be about 3 times more cost-effective to test and repair than the baseline fleet.

Even though these vehicles represent a small portion of the on-road fleet, they continue to have high failure rates, and will increase test and repair revenue for DCFs. This additional testing will also generate additional net revenue for DCO (program revenue). Motorists will face higher aggregate repair costs, as well as higher average repair costs, as it probably will be more difficult to perform durable repairs on these older vehicles. (The incremental increase in repair costs was not estimated by ERG, however, due to lack of detailed cost data on these vehicles.) The difficulty of repairing older vehicles may encourage their owners to retire these vehicles or avoid program requirements, which may increase motorists and DCF non-compliance. This would also have an adverse impact on social equity, in regards to costs being borne by vehicle owners that have older vehicles, which tend to be individuals with lower incomes.

6.2.3 Require Annual Testing for Vehicles that Failed the Initial Emissions Test of Their Previous *Drive Clean* Inspection

6.2.3.1 Current Program

The *Drive Clean* program does not currently require vehicles which initially fail their *Drive Clean* emissions test to submit to off-cycle testing. All light-duty vehicles are subject to a biennial test program.

6.2.3.2 Benchmark

Although several I/M programs have considered off-cycle testing for previously failed vehicles, none have adopted this program refinement, most likely due to the logistics of implementation and possible motorist confusion. California is in the process of adopting annual testing for previously failed vehicles for its I/M program.

6.2.3.3 Need for Change

Forty-one percent of vehicles that failed their previous initial inspection and passed a retest, and sixty-two percent of vehicles that received a conditional-pass, failed their next initial inspection. Based on analysis of a subset of vehicles that received an off-cycle test, much of this emissions increase between I/M test cycles appears to occur shortly after the vehicle passes its

retest on the first cycle; this phenomenon has been observed in every I/M program studied. Although implementing off-cycle testing will not directly improve the effectiveness or durability of initial repairs, this testing will hasten re-repairing vehicles whose repairs aren't durable and will also help to remove difficult to repair vehicles from Drive *Clean's* roads.

In Section 5, data also showed that older model year vehicles have a much higher fail-pass-fail rate than newer vehicles, which might be due to older vehicles having an overall higher likelihood of failing. One option may be to test all older vehicles more frequently, rather than only the previously failed vehicles. This may be an alternate approach but because older vehicles are less prevalent in the fleet and are also driven less than newer vehicles, this may not be the best approach for identifying most numbers of potentially failing vehicles. This also may be perceived as inequitable for motorists who drive these older vehicles.

6.2.3.4 Analysis of Option

One option for helping monitor repair durability for these high emitting vehicles is to require all vehicles that failed the initial test in their previous cycle be tested in the off-cycle year until they pass their initial test. This would either help ensure that these vehicles stay below their emission cutpoints, or require them to be repaired to cutpoint levels sooner than would be required under the current biennial test program. Once a vehicle in the "off-cycle" program passed its initial test, it would again go back to its regular biennial cycle.

The precise emission reductions and costs associated with this option are difficult to quantify, however. Annual emission measurements would be needed to determine the likely excess emissions one year after repair, specific to this subset of vehicles. In addition, average repair costs are likely to be somewhat different after just one rather than two years of deterioration.

Advantages

- Off-cycle testing will help identify and repair vehicles shown to be likely to be high polluters
- Off-cycle testing will result in additional DCF and program revenue

Disadvantages

- This option would result in additional administration work and can be confusing to motorists
- Off-cycle testing will result in additional test and repair fees paid by motorists

6.2.3.5 Recommendation

We recommend that *Drive Clean* consider requiring all vehicles that fail their initial inspection be tested one year later, in order to reduce the annual emissions from those vehicles that failed their initial inspection. These vehicles would remain on their biennial test cycle, and would be required to receive an additional off-cycle test every year until they pass the initial test in their biennial cycle.

6.2.3.6 Impact of Recommendation

This option will increase environmental and health benefits of the program, since these high-emitting vehicles will be repaired sooner than they would have been if they were allowed to wait two years until their next inspection. This may also help convince owners of vehicles that repeatedly fail to permanently retire these vehicles from the *Drive Clean* areas. We anticipate more frequent testing will be cost-effective, roughly comparable to that of the overall base case program. Annual testing will increase test and repair revenues for DCFs; the increase in test fees will generate additional revenue for DCO. We do not expect that annual testing will increase average repair costs, although the greater frequency will increase aggregate repair costs to motorists. Motorists likely will oppose this option because of the inconvenience of annual testing, and some may perceive it as being inequitable to lower-income households that are more likely to own vehicles that failed their previous emissions inspection; as a result, we expect that test, repair and registration non-compliance will increase under this option. Implementation of this option would require MTO to inform motorists on their Vehicle Licence Renewal Application of the need to pass an emissions test in order to renew their registration the following year (this field is already in place on the renewal application). The option will only be effective if conditional-passes are limited to only one per vehicle lifetime (an option explored later in this section); otherwise more motorists would be encouraged to seek conditional passes rather than full repairs for their failing vehicles.

6.2.4 Require More Frequent (Annual) Testing – Fleet Vehicles

6.2.4.1 Current Program

Currently all light-duty vehicles in the *Drive Clean* program are inspected biennially (once every other year).

6.2.4.2 Benchmark

A few programs in other jurisdictions require more frequent testing of vehicles from specific commercial fleets. For example, New York City taxicabs receive an I/M test three times a year.

6.2.4.3 Need for Change

Because certain commercial fleets, such as taxicabs or local delivery vehicles, are driven more kilometers per year than the average vehicle, it is thought that their emissions deteriorate more rapidly than the average vehicle. More frequent (annual) inspection of these vehicles will identify high emitting vehicles more quickly, hopefully leading to effective repair and reduced emissions.

6.2.4.4 Analysis of Option

This option explores requiring commercial fleets, such as taxi and local service delivery fleets, to undergo annual emissions inspections, rather than biennial inspections. Doing so would ensure high mileage commercial fleets received more frequent testing than they currently receive, which would lead to earlier identification and repair of high emitters. However, owners of affected vehicles may oppose more frequent testing, and currently taxicabs are identified at the municipal level, and are not readily identified in the MTO registration database. This would require a fair amount of administrative effort and intra-agency coordination in order to implement.

The impacts of this option are similar to those for annual testing of vehicles that failed their previous inspection, except that the emission reductions and health benefits are likely to be smaller, and consumer acceptance and perceived equity likely to be greater, as these vehicles are driven more kilometres per year than the average vehicle. However, since neither the MTO nor the *Drive Clean* Program can uniquely identify these fleets, we acknowledge that this would need to be a cooperative effort between provincial and municipal authorities, which could be a challenge for any program.

A quantitative analysis of costs and benefits for this option is not possible without detailed information on model years, vehicle types, and kilometers per year for the fleet population in question.

Advantages

- Requiring annual testing for fleet vehicles would ensure these high mileage/high-polluting vehicles are repaired more frequently than they currently are

Disadvantages

- Fleet owners would likely resist annual testing
- Annual fleet testing would be difficult to administer

6.2.4.5 Recommendation

Due to the uncertain costs and benefits, and the logistics of implementing such an option, we do not recommend that *Drive Clean* adopt this option at this time.

6.2.5 Implement On-Board Diagnostic System (OBDII) Testing for 1998 and Newer Gasoline Vehicles

6.2.5.1 Current Program

The *Drive Clean* program does not currently perform OBDII testing. Several options for implementing OBDII testing into the program are explored in the following subsections.

6.2.5.2 Benchmark

USEPA guidance recommends the OBDII test be used for pass/fail determination for 1996 and newer vehicles in US I/M programs. All I/M program jurisdictions reviewed for this evaluation, with three exceptions, use the OBDII test for pass/fail determination on 1996 and newer model year vehicles. California requires an OBDII scan *and* tailpipe emissions test of 1996 and newer model year vehicles (vehicle must pass both tests to receive an overall pass). Colorado also performs an OBDII scan and tailpipe emissions test of 1996 and newer model year vehicles, but the OBDII result is advisory only (vehicle is only required to pass the tailpipe portion of the test). Although British Columbia performs IM240 tests on 1992 and newer model year vehicles (including 1998 and newer OBDII-equipped vehicles), an OBDII scan is also performed on 1998 and newer vehicles to ensure compliance with evaporative emissions requirements.

6.2.5.3 Need for Change

All 1996 and newer vehicles in the US, and 1998 and newer light-duty vehicles in Canada, have on-board diagnostic computer (OBDII) systems that enable the quick identification

of failed or malfunctioning components of the vehicle's emission control system and facilitate vehicle repair. As outlined in Section 5, the OBDII test offers many test and emission reduction benefits to an I/M program. Specific test advantages are also listed in each of the subsections below. In 2004, 40% of the light-duty fleet subject to the *Drive Clean* program, and 55% of all light-duty vehicles, were equipped with OBDII systems, so incorporating OBDII testing into the *Drive Clean* program would affect a large portion of the vehicle fleet immediately.

6.2.5.4 Analysis of Options

6.2.5.4.1 Option 1: Implement an OBDII-only program for 1998 and newer vehicles; retain tailpipe testing on 1997 and older vehicles in existing program area.

Advantages

- OBDII monitoring has been shown to be very effective in identifying high-emitting vehicles.
- OBDII-only testing would be quicker and easier to conduct than tailpipe testing.
- OBDII-only testing reduces wear on dynamometers in current DCFs, possibly reducing maintenance costs, extending equipment life and delaying future capital expenditures.
- Would provide the opportunity for future program expansion into new OBDII-only regions (testing only 1998 and newer vehicles, no tailpipe testing)

Disadvantages

- Like tailpipe testing, OBDII testing is not entirely immune to false failures (failing vehicles with nothing wrong) or false passes (passing vehicles with true high emissions)
- Emission reductions attributable to an OBDII-only program would need to be confirmed using some type of supplemental testing or modeling.
- Relying entirely on OBDII for these newer vehicles is somewhat risky since the performance of OBDII systems on high-mileage, older vehicles, and on newer ultra-low emission vehicles (ULEV) remains uncertain.
- May require program test fee limit increase to allow DCFs to recover capital necessary for equipment, although the increased revenue from repairs may more than offset the required capital cost.
- Allowing OBDII-only facilities to join in the future could result in some industry dissatisfaction issues, since equipment costs for new OBDII-only DCFs would be much lower than those for "traditional" (tailpipe) DCFs.

Table 6-14 presents emissions reductions based on implementing OBDII testing in lieu of ASM for 1998 and newer vehicles. As expected, the estimated reductions become rapidly larger in future years as OBDII vehicles come to dominate the test fleet.

Table 6-14. Emissions Reductions from OBDII Implementation (tonnes/yr)

Calendar Year	2005	2010	2015
NOx	252	824	1,567
HC	518	1,389	2,395
CO	3,065	9,747	16,869
NOx+HC+CO/7	1,208	3,605	6,371

An overall fleet fail rate was calculated based on OBD and ASM failure rates obtained from a 2004 evaluation of California Smog Check data.[36] Vehicle test numbers, fail rates, and resulting emission benefits are presented in Table 6-15, while associated costs to the different parties are provided in Table 6-16. Note that incremental Government costs were significant for this option, possibly impacting the break-even point for revenue neutrality. Also, due to lack of reliable future OBD fail rate projections, ERG did not develop repair estimates or cost projections for the 2010 and 2015 evaluation years. Table 6-17 presents OBDII implementation cost effectiveness figures for 2005.

While substantial emission reductions may be obtained through adoption of OBDII testing in 2005, the estimated OBDII fail rate for 1998 and newer vehicles (4.4%) is much higher than the corresponding ASM rate for these same model years (1.95%). This results in a relatively high dollar per tonne estimate for OBDII relative to the current I/M program. But as discussed elsewhere, OBDII tests are designed to generate preventative repairs, the benefit of which is not clearly captured in these estimates. In addition, it is possible that the OBDII and corresponding ASM fail rates will become closer in the coming years, thereby improving the incremental cost-effectiveness of OBDII in the future.

The relatively high OBDII fail rates in 2005 also result in a substantial increase in repairs and DCF revenue, although total Government revenue would remain the same.

[36] Klausmeier, Rob, "Feasibility of Using OBDII Tests as a Screening Tool," presented at NCVECS, September 2004.

Table 6-15. Impact of Option on Subject Fleet and Emission Reductions OBDII for 1998 and Newer Vehicles - 2005 Calendar Year

Model Year	# of Vehicles[37]	% of Fleet[38]	Failure Rate	Failing Vehicles	Emissions Reductions (Tonnes/Yr)		
					HC	CO	NOx
Base	2,292,222	37.8%	9.8%*	225,096	7,502	174,662	7,371
OBD	2,292,222	37.8%	12.1%^	277,359	8,020	177,727	7,623
Delta	-	-	*2.3%*	*52,263*	*518*	*3,065*	*252*

* ERG by-model year analysis, even model year vehicles
^ 2004 data from California Smog Check Program

Table 6-16. Impact of Option on 2005 Costs & Revenues OBDII for 1998 and Newer Vehicles (Millions of 2005 Canadian $/Yr)

	DCF Costs		Government Costs	Motorists Costs		Program Revenue	
	Fixed	Variable	Total	Tests	Repairs	To DCFs	To Gov't
Base Case	45.2	118.0	19.7	83.8	90.0	147.8	26.0
OBD (98+)	46.4	137.9	21.2	83.8	110.8	168.6	26.0
Delta	*1.2*	*19.9*	*1.5*	*0*	*20.8*	*20.8*	*0*

Table 6-17 Cost Effectiveness for OBDII Implementation (2005 Canadian dollars/tonne HC+NO_x+CO/7)

Calendar Year	2005
Incremental Costs and Benefits over ASM testing	$16,488
Modified I/M as a whole	$4,888

While the incremental cost-effectiveness for OBDII appears relatively high, note that this estimate does not account for the potential future cost savings associated with OBD's preventative diagnostic value. In addition, there is reason to believe the cost-effectiveness will improve in the future – as discussed in Section 5.1.2.5.3, preliminary high-mileage vehicle results suggests OBDII and tailpipe failures may have greater overlap as vehicles age with OBD codes less indicative of "preventative maintenance" needs, and more indicative of true emissions failures.

[37] DesRosiers Report.
[38] Derived from DesRosiers Report – 2005 test fleet as percentage of total fleet (all model years, all phases).

6.2.5.4.2 Option 2a: OBDII *and* tailpipe on 1998 and newer (must pass both), ASM only for 1997 and older vehicles

Advantages

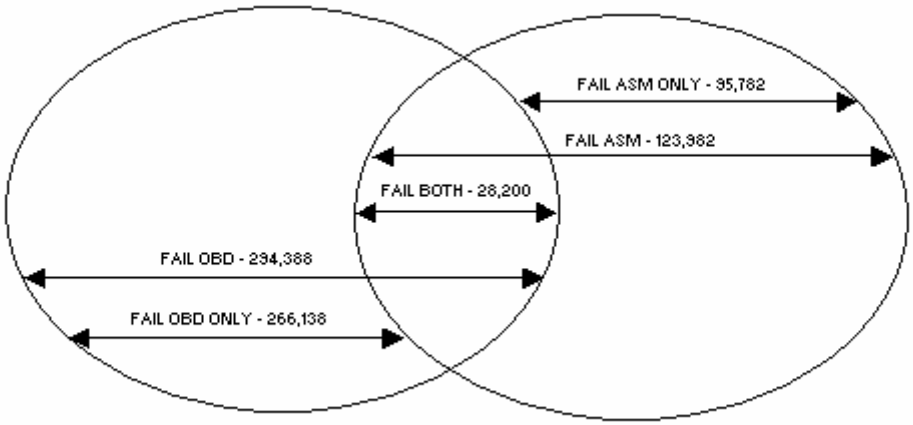
- Allows identification and repair of a greater number of vehicles with high emissions and malfunctioning components.
- Will help catch any tailpipe and OBDII false passes
- Allows ASM testing to continue if OBDII performance with high-mileage and/or ultra-low emission vehicles is unacceptable (too many false fails or passes)
- As vehicles age, ASM results could be used to monitor performance of OBDII systems of high-mileage vehicles
- DCFs already have ASM test equipment.

Disadvantages

- More onerous and inequitable for motorists with OBDII vehicles, who would have to pass two tests in order to register their vehicle.
- Could illustrate differences between the two tests, and undermine motorist confidence in OBDII and/or tailpipe inspection (Several studies have shown a small overlap between OBDII-failures and tailpipe test failures. If vehicles are seen to fail one inspection but not the other, motorist confidence in the inspection results might be undermined.)
- Higher costs to the inspection station due to equipment and longer test times
- Higher costs and longer test times for motorists
- No reduction in wear on program test dynamometers. Although the expected equipment life for program dynamometers is approximately 20 years (from equipment manufacturer estimates), some in-ground dynamometers used in the *Drive Clean* program appear to be deteriorating more rapidly due to insufficient drainage of ice, snow, water, and salt. Although many factors can influence a dynamometer's useful service life (i.e., type and amount of usage, maintenance and cleaning, storage practices, and type of testing/loading), continued use of these dynamometers at the current service level may result in DCFs having to purchase new dynamometers before this 20-year period. OBDII-only testing on 1998 and newer vehicles would reduce the deterioration rate of these dynamometers.
- More complex inspection systems and software logic

Data collected as part of the California and Arizona I/M programs was used to assess the combined benefit of an OBD and ASM program. Figure 6-1 shows the numbers of vehicles that failed ASM, OBD, and both tests from a sample of about 5.1 million vehicles in California. All

vehicles were subject to both ASM and OBD tests. This data was used to estimate the cost of a possible dual ASM/OBDII test program for Ontario. The California data shows that out of the 5.1 million vehicles tested, about 390,000 (7.6%) fail for either the ASM or the OBD tests. In the California dataset about 5.7% failed OBD, 2.4% fail ASM, and about 0.5% fail both ASM and OBD tests. More importantly, almost 77% of the vehicles that fail ASM pass the OBD tests. These vehicles are responsible for the "extra" emissions reduction possible with the ASM+OBD test scenario.



Total number of vehicles = 5.1 million

Figure 6-1 OBDII and ASM Test "Overlap"

Information regarding the "extra" emissions reduction possible with a tailpipe and OBD program compared to OBD or tailpipe only programs are generally hard to quantify in available literature. Based on information contained in a de la Torre Klausmeier presentation for the Arizona I/M program[23], ERG determined that vehicles that fail both tailpipe and OBD testing have emissions that are approximately 40% higher than vehicles failing either test. To calculate the additional benefit of concurrent tailpipe and OBD testing, ERG added together emissions benefits, calculated using MOBILE6.2C, from OBD testing, and added them to 40% of the benefits expected from ASM testing.

Table 6-18 presents ERG's emissions reduction estimates for implementing a dual OBDII/ASM test requirement, relative to the base I/M program.

Table 6-18. Emissions Reductions from dual OBDII/ASM Testing (tonnes/yr)

Calendar Year	2005	2010	2015
NOx	637	1,905	3,194
HC	988	2,232	3,429
CO	14,523	43,181	68,167
NOx+HC+CO/7	3,699	10,305	16,362

While dual testing may have a moderate potential for emission reductions, the impacted portion of the fleet is expected to be fairly small relative to the single OBDII test scenario, as shown in Table 6-19. Similarly, incremental costs relative to the single OBDII test are also fairly low (see Table 6-20). Government revenues would remain unchanged under this option (again relative to single OBDII testing).

Table 6-21 presents the resulting cost effectiveness estimates for 2005 – subsequent years were not modeled, again due to uncertainty associated with long-term OBDII fail rates.

Table 6-19. Impact of Option on Subject Fleet and Emission Reductions OBDII +ASM for 1998 and Newer Vehicles - 2005 Calendar Year

Model Year	# of Vehicles[39]	% of Fleet[40]	Failure Rate	Failing Vehicles	Emissions Reductions (Tonnes/Yr)		
					HC	CO	NOx
Base	2,292,222	37.8%	9.8%*	225,096	7,502	174,662	7,371
OBD+ASM	2,292,222	37.8%	13.1%	300,281	8,490	189,185	8,008
Delta	-	-	*3.3*	*75,185*	*988*	*14,523*	*637*

* ERG by-model year analysis, even model year vehicles
^ 2004 data from California Smog Check Program

Table 6-20. Impact of Option on 2005 Costs & Revenues OBDII + ASM for 1998 and Newer Vehicles (Millions of 2005 Canadian $/Yr)

	DCF Costs		Government Costs	Motorists Costs		Program Revenue	
	Fixed	Variable	Total	Tests	Repairs	To DCFs	To Gov't
Base Case	45.2	118.0	19.7	83.8	90.0	147.8	26.0
OBD+ASM (98+)	46.4	143.8*	21.2	83.8	119.9	177.7	26.0
Delta	*1.2*	*25.8*	*1.5*	*0*	*29.9*	*29.9*	*0*

* Incremental labor for additional test not included

[39] DesRosiers Report.
[40] Derived from DesRosiers Report – 2005 test fleet as percentage of total fleet (all model years, all phases).

Table 6-21 Cost Effectiveness for Dual OBDII/ASM Testing (2005 Canadian dollars/tonne HC+NO_x+CO/7)

Calendar Year	2005
Incremental Costs and Benefits over ASM testing	$10,350
Modified I/M as a Whole	$4,745

In this case the incremental cost-effectiveness is still higher than the base program, but more favorable than OBDII alone. On the other hand, our analysis did not account for the incremental inspection time required for both tests, which would tend to increase the above value somewhat (although most of the cost increase would be attributable to additional repairs).

6.2.5.4.3 Option 2b: OBDII on 1998 and newer vehicles, with tailpipe as fallback if vehicle fails OBDII

Advantages

- Allows program to gather paired OBDII/ASM information for vehicles that fail the OBDII test
- Better public acceptance (two chances to pass)
- Possibly better DCF acceptance, generally quicker test to administer and less wear on program test dynamometers (as compared to dual OBDII-ASM testing on all 1998 and newer vehicles)

Disadvantages

- Would lose benefits associated with catching OBDII false passes.
- Could illustrate differences between the two tests and undermine confidence in OBDII.
- Higher costs to the inspection station due to equipment and longer test times
- Higher costs and longer test times for motorists
- More complex inspection systems and software logic

ERG did not quantify incremental emissions or costs for this option due to the lack of specific emissions data on this subset of vehicles.

6.2.5.4.4 Option 2c: OBDII on all 1998 and newer vehicles, with a small sample of vehicles also given an ASM test for program evaluation purposes only

This program evaluation testing could be controlled by the VETS (information transmitted during the "get vehicle info" call between OTU and VETS would trigger the OTU to run dual testing). Vehicle selection could be based on mileage, vehicle type, gross vehicle

weight rating, model year, or a combination of those parameters, to ensure stratified sample representative of fleet is obtained. Sampling could also be random, as well. This would be a non-voluntary test, issued as part of the *Drive Clean* test program.

Advantages

- This would allow the collection of emission information on a subset of the fleet receiving OBDII-only tests

Disadvantages

- Perceived inequity of motorist's tests (some vehicles receive two tests, although one is used for internal data only) – Could lead to public confusion, dissatisfaction
- Results in unpredictable test and wait times
- Higher test costs that could not be passed to the motorist (unless applied to program-wide fee)
- More complex inspection systems and software logic

This option is essentially designed for program evaluation with completely uncertain emission benefits. Costs would be directly proportional to the scale of the test effort.

6.2.5.4.5 Option 2d: Enforced MIL check only with existing tailpipe test

This would consist of a visual MIL-only check, where the inspector would manually enter the MIL illumination status into the OTU.

Advantages

- Allows quick and inexpensive check of MIL without equipment upgrade

Disadvantages

- Inspector must enter MIL status manually, allows for fraud and incorrect entry
- Provides no diagnostic information if MIL is illuminated
- Vehicles with MILs that are off only because the vehicle is "not ready" would not be identified (i.e., codes reset to mask problem during inspection).

Quantification of costs and benefits for this measure would require specific (and unavailable) information regarding MIL illumination vs. OBDII system codes.

6.2.5.5 Recommendation

For 1998 and newer vehicles, we recommend retaining the ASM test but replacing the post-ASM curb idle test with an OBDII test (vehicle must pass both), for three reasons:

- Several states in the US (including California, Colorado, and Oregon) have seen evidence of vehicles with high tailpipe emissions which have passed the OBDII test. This may be evidence of potential errors of omission (i.e. false passes) with certain OBDII systems.
- Retaining the ASM test will provide emission results, which in conjunction with repair data, may be used to determine if OBDII testing is resulting in false failures. The emissions information may also be used to estimate the cost effectiveness of repairing individual vehicles that fail an OBDII test, as vehicles accumulate high mileage and age; and
- ASM equipment already exists in Ontario;

California and Colorado currently require an OBDII scan along with a tailpipe emissions test of OBDII-equipped vehicles (although Colorado does not fail on OBDII). Because OBDII criteria are different than criteria used for the ASM test, implementing OBDII along with ASM will increase the number of vehicles that fail inspection, and lead to earlier repair of high emitting vehicles, thus increasing the emission reductions from the program.

Finally, there are uncertainties regarding OBDII performance in high mileage and/or old vehicles and in LEV, ULEV and SULEV vehicles. Retaining the ASM test allows the estimation of emission reductions from OBDII I/M testing.

6.2.5.6 Impact of Recommendation

Adding OBDII testing to 1998 and newer vehicles slightly raises the cost per tonne of the overall program (neglecting any small amount of emission reductions lost by removing the curb idle test for 1998 and newer vehicles). Dual-testing would result in an increase in program emission reductions, as vehicles that fail either of the two tests will be classified as a “failed” vehicle. As the OBD and ASM tests identify different vehicles as “fails”, this would increase the number of failed vehicles. This will similarly have a positive environmental impact. The total number of repairs would likely increase, as well as the average per-vehicle repair cost (since vehicles are required to pass two different types of tests).

The implementation of dual testing is likely to have a negative social impact, as motorists with model year 1998 and newer vehicles are required to pass two different types of tests while older vehicles are not. In situations where a vehicle passes one test but fails the other, the

motorist may feel that the test that failed the vehicle is inaccurate, since the vehicle was "proven" to be clean by the other test. In addition, test discrepancies can undermine public and industry confidence in the overall test program. Public and industry outreach and education can greatly mitigate this misperception.

We believe that requiring dual ASM and OBDII testing will cost DCFs additional money, due to increased test complexity, software and hardware changes, longer test times, and relative to the single OBD test option, wear and tear on equipment, depletion of consumables, and other equipment maintenance requirements. In addition, dual testing will likely require many DCFs to pay for ongoing service contracts with equipment manufacturers (probably similar to current contract coverage).

6.2.6 Ensure Vehicles Undergoing ASM Testing are at Operating Temperature

6.2.6.1 Current Program

Currently light-duty vehicles are required to be "preconditioned" (or warmed up) prior to the start of the ASM test, in order to reduce the potential for false failures. The duration of this preconditioning is increased to 90 seconds in the winter to reduce the likelihood that some vehicles are falsely failed for HC or CO, and reduced to 30 seconds in the summer to reduce the likelihood that some vehicles are falsely failed for NO_x.

6.2.6.2 Benchmark

Most of the jurisdictions surveyed in this study require some form of preconditioning for tested vehicles; for example, many IM240 programs, and USEPA recommendations, require that vehicles be tested for 8 minutes before failing. Most ASM programs require a two-mode ASM test which includes the 5015 mode followed by the 2525 mode.

6.2.6.3 Need for Change

Results of studies conducted on in IM240 programs in Arizona and Colorado have shown preconditioning to influence test outcome, with inadequate preconditioning resulting in false failures. USEPA guidance recommends vehicles be tested for 8 minutes (two successive IM240s) before failing. Although little data is available on the effect of preconditioning on ASM test results, preconditioning influences are expected to be similar for these different types of tailpipe tests. Review of *Drive Clean* test records supports this expectation.

6.2.6.4 Analysis of Options

During a *Drive Clean* ASM test, vehicles with emissions between 100% and 150% of the vehicle's cut points are given an immediate second chance ASM test. During 2004, one-third of all failed vehicles received this "second chance" test, and of those vehicles, 40% passed. Analysis of overall *Drive Clean* failure rates by season shows consistently higher failure rates in summer months for all three pollutants, which may be an indication of inadequate preconditioning. This seasonal variation, along with the number of vehicles passing their second chance test and in conjunction with results of preconditioning studies performed on Arizona and Colorado I/M data, seem to imply that some vehicles may be receiving inadequate preconditioning during the *Drive Clean* test.

One concern with requiring year-round 90-second preconditioning has been that during the summer months, this additional warm-up time will result in a substantial increase in NO_x emissions (failures) due to engine overheating. However, analysis of NO_x values for vehicles that received both "first chance" and "second chance" tests revealed that only 5% of these vehicles had substantially higher NO_x emissions during the "second chance" test. However, this analysis also showed that nearly as many vehicles (4%) had substantially higher CO emissions during the second chance test, which implies in general that the emissions increases for this small percentage of vehicles is likely due to an influence other than overheating.

Note that other methods are available to ascertain whether or not vehicles are adequately "warmed up" when ASM emission measurements begin. One such way is through a test software change. Pass/fail determination for the ASM test is based on *stable* emissions measured during a 10 second window. One way to achieve the goal of warmed up operation may be to extend this measurement window to 30 seconds rather than 10 seconds (which would require emissions stability over a longer period of time, thus ensuring adequate warm-up). However, the 30-second measurement window is not used in any other program and this non-standard methodology would lead to increased complexity in comparing Ontario's program with programs in other jurisdictions. In addition, this more stringent requirement could result in more vehicles being improperly failed for emissions instability (rather than high emissions). Alternatively, DCO could require that all vehicles that fail the initial test receive a second chance test. This would result in any vehicle that falsely fail the initial test because it was not adequately preconditioned receiving a second chance test.

Our recommendation of the preconditioning time increase is based on the ease of implementation of the 90 seconds preconditioning requirement. DCO could implement the 90

seconds preconditioning without a change in analyzer software. A change to the measurement window or requiring that all failing vehicles receive a second chance test would require a modification of the existing analyzer software.

ERG did not estimate the incremental cost or benefits associated with this option due to the uncertainty in the baseline and resulting number of false failures.

Advantages

- Implementing additional warm-up times (either preconditioning or second chance warm-ups) will result in a reduction of vehicles falsely failed due to testing below optimum operating temperatures
- Implementing either of the options should be fairly simple to administer
- Reducing the number of "borderline" false failures (due to vehicles being tested below optimum operating temperatures reduced the likelihood of "inaccurate" testing often reported by program critics

Disadvantages

- Although not shown in ERG's analysis, additional preconditioning (or second-chance warm-up) could result in additional NOx failures due to engines overheating
- Additional warm-up times (either preconditioning or second chance warm-ups) will result in longer test times

6.2.6.5 Recommendations

We recommend that *Drive Clean* consider requiring a 90-second preconditioning period year-round. Analysis of data collected on a random sample of vehicles could be performed in order to quantify the effect of preconditioning time and ambient temperature on false HC and CO failures and false NO_x failures. Alternatively, DCO could require that all vehicles that fail the initial test receive a second chance test (regardless of emission levels at the time of the first chance fail). This would result in any vehicle that falsely fails the initial test due to insufficient preconditioning receiving a second chance test.

6.2.6.6 Impact of Recommendations

As shown in Section 5, failure rates in Ontario appears to follow changes in the test preconditioning period and ambient temperature. We anticipate that using a 90-second preconditioning period year-round will reduce the potential for false failures. Because repairs to

vehicles that falsely-failed their initial test rarely result in actual emission reductions, this option will have little, if any, environmental or health impacts, but will reduce the cost to consumers of unnecessary repairs and retesting (lower aggregate costs to motorists for repairs). Because this option involves only a minor software change (test file update), it is relatively inexpensive and easy to implement. We anticipate that this option will be slightly cost-effective, because it will not affect the number of initial tests or require a change in test fees. It will also not affect the program's net revenue. Although this option is expected to reduce the potential for false failures, benefiting a presumably small number of motorists, test times will be increased by a minute for all vehicles tested in the summer, and by 30 seconds for all vehicles tested in the spring and fall. Given that inspections already take several minutes on average, this small increase in test times is a small inconvenience for most motorists. In addition, this option will improve the equity of the program, as we anticipate that it will reduce the variation in fail rates by season. We don't anticipate that this option will have an impact on DCF or motorist compliance.

6.2.7 Cutpoint Modifications

For this option, we consider changes to the ASM cutpoints currently used in the *Drive Clean* Program. Since only 7% of all light-duty gasoline vehicles receive a fall-back TSI test, and only 4.6% of those vehicles fail the fallback test, changes to the two-speed idle cutpoints used for light-duty gasoline vehicles were not considered in this evaluation. Similarly, we do not consider changes to the post-ASM curb idle cutpoints, since only 10% of all vehicles that failed the *Drive Clean* test failed the curb idle test but passed the ASM test.

6.2.7.1 Current Program

Drive Clean ASM cut points for light duty vehicles were tightened in January 2003 and again in January 2005.

6.2.7.2 Benchmark

It is difficult to compare cut points across I/M programs, as they typically are a function of vehicle type, age, and test weight. However, we applied the current California cut points to the *Drive Clean* fleet to derive the average cut points by vehicle type and model year for each pollutant. Current *Drive Clean* ASM cutpoints for all pollutants for LDTs, and for CO for cars, are more stringent than those currently in use in California. However, *Drive Clean* HC cutpoints for 1993 and newer cars, and NO_x cutpoints for 1987 and older cars, are less stringent than those in California.

6.2.7.3 Need for Change

Cut points can be tightened (made more stringent) to increase the failure rate, and potentially increase emission reductions, in any I/M program. However, cut points should not be made so tight that many vehicles cannot be repaired to meet the cut points.

6.2.7.4 Analysis of Option

Based on our comparison of the *Drive Clean* cut points with California cut points (Section 5.1.2.8), we considered tighter HC cutpoints for 1993 and newer cars, and tighter NO_x cutpoints for 1987 and older cars. Another option would be to adopt tighter cut points for specific makes and models that can be repaired to meet more stringent cut points.

Adopting tighter cutpoints, either for particular vehicle types, model years and/or pollutants, or for specific vehicle makes and models, will result in increased fail rates. This in turn will result in increased emission reductions and health benefits. The total number of passing tests, test fees generated, and program net revenue will not be affected. However, this option will increase the number of repairs required as well as the average cost of repair; this in turn will increase costs to motorists, and increase revenues to repair DCFs. In general, attempting to repair vehicles to tighter cutpoints reduces the overall cost-effectiveness of repairs, as emissions reductions decrease and repair costs increase. Although there has not been strong motorist opposition to previous changes in cut points, consumers may oppose even tighter cutpoints, and the resulting higher fail rates, although they may result in more durable repairs (particularly vehicle-specific cutpoints). The effect of this option on consumer equity depends on the specifics of the changes; if only cutpoints from older model years are tightened, this would clearly decrease equity. However, if only cutpoints for newer model years are tightened, one could argue that this improves equity, as households with higher incomes tend to own newer vehicles. Similarly, vehicle-specific cutpoints would increase consumer equity. Cutpoint changes would be easy to implement, requiring only minor changes to the OTU software. It likely will be difficult to repair some vehicles to meet tighter cutpoints. While this measure will encourage some of these vehicles to be permanently removed from the *Drive Clean* area, it is also likely to lead some motorists to avoid program requirements. Motorists may put additional pressure on DCFs to engage in test fraud to ensure that their vehicles pass the tighter cutpoints.

Advantages of tightening *Drive Clean* Cutpoints

- Tighter cut points will result in more vehicles being repaired, ultimately leading to larger emission reductions.

- Tighter cut points may result in more vehicles being permanently removed from the *Drive Clean* areas.

Disadvantages of tightening *Drive Clean* Cutpoints

- Repairing vehicles to tighter cut points likely will increase average repair costs.
- It may not be possible to repair some vehicles to meet excessively stringent cut points.
- Tighter cut points may increase DCF and motorist noncompliance with program requirements.
- Tighter cut points may result in some vehicles being falsely failed.

Since the MOBILE model does not allow the user to fine-tune cutpoints for ASM (the only option being "phase-in" or "final"), ERG was not able to quantify likely reductions from this measure. In addition, cost estimates were not possible either without actual data on the increase in fail rates associated with the tighter cutpoints.

6.2.7.5 Recommendation

Since the current *Drive Clean* cutpoints were adopted in January 2005, they probably should not be changed until at least January 2007. California is currently investigating more stringent cut points in their ASM program; we recommend that *Drive Clean* monitor the results of the California study before adopting more stringent cut points.

6.2.8 Adopt Motorcycle Testing Requirement

This option would require motorcycles to undergo a biennial two-speed idle test.

6.2.8.1 Current Program

The *Drive Clean* program does not currently require that motorcycles receive an emissions test.

6.2.8.2 Benchmark

One I/M program, Arizona, requires emissions testing for motorcycles, which receive a biennial two-speed idle test. California is considering adding motorcycles to its program.

6.2.8.3 Need for Change

Requiring motorcycles to pass a biennial TSI test will increase the emission reductions and health benefits from the program.

6.2.8.4 Analysis of Option

Implementing a biennial TSI emission test would allow the *Drive Clean* program to realize an emission benefit from motorcycle testing. There currently are more motorcycles (118,000) registered in the *Drive Clean* area than light-duty diesel vehicles (106,000) or heavy-duty non-diesel vehicles (28,000), and almost as many as the number of registered heavy-duty diesel vehicles (166,000). However, motorcycles are probably operated fewer kilometers per year than most other vehicle fleets.

Including motorcycles in the program would result in a large increase in the number of initial tests, and also would increase test fee revenue and generate additional income for the program. This option could be implemented without a change in the OTU hardware, although a software change would be necessary. In addition, several issues would need to be addressed prior to initiating a motorcycle test program. Some examples include determining what cutpoints would be appropriate for Canadian motorcycles, how would repairs be performed (since test and repair and repair-only DCFs would not typically be qualified to perform motorcycle repairs), would a new class of motorcycle test and/or test and repair facilities be required, what specific test problems might be encountered during motorcycle testing, what model years should be included, and what level of effort would be required in developing software changes and motorcycle lookup tables. Repair facilities would benefit from performing the additional repairs required for motorcycles that fail the test. It is unclear what effect repairs to motorcycles would have on the repair costs averaged across all vehicle types, although since they have not been previously subject to I/M testing, we anticipate that the their repair will cost less, and will be more cost-effective, on average than for other vehicle types.

Motorcycle owners would resist this option, although owners of other vehicles may perceive this as increasing social equity. This option will not require any hardware changes to the OTUs, as the TSI test equipment can be readily used on motorcycles; however, software changes would be required. This option likely would increase non-compliance with program requirements, on the part of both DCFs and motorists, and would increase administrative costs associated with implementing and maintaining a new test program. An assessment of the emission contribution of motorcycles would need to be weighed against the testing implementation issues in determining if motorcycle testing is a viable option.

Advantages

- Requiring motorcycles to pass a biennial TSI test will increase the emission reductions and health benefits from the program

Disadvantages

- Appropriate cutpoints, model years, etc. for Canadian motorcycles would need to be established
- Repairs would typically need to be performed by non-accredited repair facilities
- Software changes required for testing motorcycles would need to be established

Due to the above uncertainties ERG did not attempt to quantify the costs or benefits associated with this option.

Recommendation

Because only one program emission tests motorcycles, we do not recommend that *Drive Clean* include motorcycles in their program at this time. However, we do recommend that *Drive Clean* analyze Arizona's experience in testing motorcycles, as well as monitor California's assessment of this option. In particular, the analysis should determine the emission reduction potential and cost-effectiveness of testing motorcycles, and address how DCFs can be certified to repair motorcycles, motorcycle testing issues, what cut points to use, and which model years to include.

6.2.9 Perform a LDD Test Pilot Program

6.2.9.1 Current Program

The current emissions test for light duty diesel vehicles is an inspection for visible emissions at the tailpipe during a five-minute period with the vehicle at idle. If more than a trace or occasional puff of smoke is observed for more than five seconds in any one-minute period the vehicle fails the emissions test.

6.2.9.2 Benchmark

With the exception of Arizona and British Columbia, no I/M jurisdictions surveyed for this study performs LDDV testing. In Arizona, a loaded/idle test is performed for 1967 and newer LDDVs. In British Columbia, opacity is measured while the vehicle is driven on a loaded following a defined set of accelerations, decelerations, and cruises (D147 drive cycle).

6.2.9.3 Need for Change

Assuming that not all LDDVs in Ontario are perfectly maintained, the current fail rate of zero-percent attests to this test's lack of stringency. Since LDDVs (both passenger cars and trucks) represent such a minor fraction of the Ontario fleet VKT (around 1.5%), the inconvenience of testing these vehicles (relative to the minimal emissions benefit) is large to LDDV owners (even when pre-test adjustments to these vehicles, such as tune-ups, are considered). In addition, the subjective nature of this test (the DCF inspector's qualitative judgement on whether the vehicle is "excessively" smoking), renders a "fail" test disposition difficult to enforce, subject to dispute, and can undermine confidence in LDDV testing. The minimal emissions benefit of the current LDDV test may not warrant the program's burden on owners of LDDVs.

6.2.9.4 Analysis of Option

Sufficient information was not available regarding PM and NO_x emissions from Ontario's LDDV fleet in order to develop options for changes to the LDDV test program. A pilot investigation, which could be performed in conjunction with the HDDV pilot investigation (discussed later in this section), may be of benefit in helping find ways for improving the LDDV test program. The pilot program could be used to evaluate viable test types and appropriate cutpoints. The pilot project should test a representative sample from the LDDV fleet. Sample vehicles could be measured as currently tested in *Drive Clean* and on a dynamometer whenever possible using the D147 cycle (as is done in British Columbia's AirCare program) and a static loaded test (such as that provided for in the *Drive Clean* Guide, but with a higher load setting). Consideration of using the J1667 method could be made, although the inherent risk of timing belt failure may exclude this as a viable option. The study should be designed to quantify opacity and NO_x benefits of each type of test vs. necessary expenditures. Other issues, such as the need for DCFs to purchase additional LDD test equipment, should be considered in the pilot study.

In order to minimize program changes, any LDDV program changes made based on results of the pilot study could be implemented after the pilot study is completed (continue with existing program until pilot is complete).

Advantages

- Conducting a pilot study could help the *Drive Clean* program proceed with the most cost effective program change possible
- A LDDV pilot study could be performed in conjunction with a HDDV pilot study, thereby reducing overall study costs

Disadvantages

- LDDVs constitute a small fraction of the Ontario fleet VKT, so program changes may not justify the expense and inconvenience of program changes
- LDDV test options are somewhat limited in comparison with LDGV test options

This option is essentially designed for evaluation with highly uncertain emission benefits. Costs would be directly proportional to the scale of the pilot test effort.

6.2.9.5 Recommendation

Due to the lack of information regarding PM and NO_x emissions from LDDVs in the *Drive Clean* fleet, we recommend additional information be gathered regarding these vehicle's emissions prior to making any program changes. One way of acquiring the needed information is to conduct a LDDV pilot study, perhaps in conjunction with a HDDV pilot study. Our review indicates the current LDDV test program may not be providing valuable emission reduction benefits.

6.2.9.6 Impact of Recommendation

Conducting such a pilot study would require additional program funds, although the study could possibly be partially supported (provision of equipment and testing services) by LDDV test equipment manufacturers interested in program involvement. This study should be conducted at a location within reasonable proximity to an adequate number of LDDVs. Performing this study in conjunction with a HDDV testing pilot study could reduce the total cumulative cost of conducting these studies.

6.2.10 Evaluate Effectiveness of Evaporative Checks for Gross Liquid Leakers

6.2.10.1 Current Program

Drive Clean currently performs a general visual inspection of all vehicles prior to their emission's test. Any vehicle found to have visible fluid leaks is rejected from testing.

6.2.10.2 Benchmark

California Smog Check is the only program to have adopted a liquid leak test specifically to identify vehicles with especially high evaporative emissions[41]. Checks for liquid leaks are

[41] D. Amlin, R. Carlisle, S. Kishan, R. Klausmeier, "Evaporative Emissions Impact on Smog Check," August 2001.

included in the visual inspection. The test does not require any disassembly or components, simply a flashlight and mirror.

6.2.10.3 Need for Change

Evaporative emissions occur when fuel evaporates and escapes into the air before it can be burned in the engine. Fuel can evaporate from a number of different places, including the engine, fuel tank, fuel lines, and carburetor. Fuel also evaporates when the gas cap is missing, damaged, or not properly tightened. Evaporative emissions can be a relatively large fraction of total mobile source hydrocarbon emissions. In fact, according to MOBILE6.2C using typical Ontario summertime conditions and test program, evaporative emissions are responsible for about half of all HC emissions from light-duty gasoline cars and trucks operating in 2005. In addition, a CRC study found that, for a sample fleet of vehicles greater than 6 years of age, 50% of evaporative emissions were from gaseous leaks, while 50% were from liquid leaks. Also, 30 vehicles with evaporative leaks that were repaired achieved 91% reductions in running loss evaporative emissions. The largest reductions were achieved for the vehicles that started out with the highest initial evaporative emissions – specifically the liquid leakers.[42]

6.2.10.4 Analysis of Option

This option would enhance what is currently performed for a *Drive Clean* test by requiring a visual inspection of fuel lines, system, tank, and vapor recover system comments for cracks, breaks, or evidence of current or past fuel leaks, similar to what is currently performed for the BAR inspection. The BAR program instructs I/M technicians to visually inspect for:

"Any fuel emanating from the vehicle's fuel delivery, metering, or evaporative system in liquid form that has created a visible drop or more of fuel on a component of a vehicle's fuel delivery, metering, or evaporation system or has created a fuel puddle on, around, or under a component of a vehicle's fuel delivery, metering, or evaporation system."[43]

The most promising current addition to the evaporative pressure test would be the inclusion of a liquid leak (GLL) check within the current *Drive Clean* testing framework. Other evaporative tests such as "sniffer" tests and vehicle profiling are, at the present time, in the conceptual stage, and require more development and pilot studies before they can be adopted for use in an I/M program.

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[42] Eng, K., H. Haskew, T. Liberty, R. Reuter, "Running Loss Emissions from In-Use Vehicles," CRC Project E-35-2, February 1999.

[43] *Liquid Fuel Leak Inspection Process and Implementation,* BAR Smog Check Advisory, September 10, 2001.

The identification and repair of the few vehicles with gross liquid leaks may provide significant VOC reductions and health benefits related to ozone and certain toxics exposure (such as benzene). For example, calculations using California ARB data indicate liquid leaks contribute an average 4.26 g/mi (although leaks may be as high as 40 g/mi for an individual leaking vehicle). The California Bureau of Automotive Repair estimates general fuel and evaporative control system repairs of liquid leaks could lead to between 8 and 35 tons/day HC reductions statewide. The anticipated low cost of repairs should also provide very cost-effective emissions reductions. In addition, financial impacts on test and repair DCFs should be slightly positive, due to increased repair revenue, and relatively small to the average motorist, given the low anticipated incidence rates. However, this test would add time and complexity to the *Drive Clean* test, which would either result in a higher test fee (motorist burden) or higher DCF (labour) costs per test. Although social impacts such as customer acceptance could be slightly positive, to the extent that the GLL check is communicated to have possible safety and fuel saving benefits, the subjective nature of the inspection (DCF inspector's visual assessment) could result in some program inequity (with regard to social acceptance) as some inspectors would undoubtedly apply more scrutiny than others when conducting the GLL inspection. Program impacts associated with oversight should be minimal.

Advantages of implementing a supplemental GLL check

- Effective identification and repair of high evaporative emitters offers a potentially large source of HC reductions.
- Once identified, repairs of GLLs could be very cost-effective. Repair costs for GLLs are commensurate with other repair costs (California BAR estimates repair costs for GLLs of US $56 for carbureted vehicles, US$142 for fuel-injected vehicles[44], as compared an overall average repair cost of US $128 for any type of repair in California)[45]. Although fuel-injected GLL repair cost value is higher than the "overall" repair cost value, the difference is small relative to the benefit of repairing vehicles with raw fuel leaks.
- While OBDII evaporative system checks are designed to identify pressure system failures, it cannot identify liquid leaks. Therefore liquid leak checks should continue to be beneficial well into the future.
- The actual cost associated with performing visual GLL checks are small compared with the total time required to conduct a *Drive Clean* test.

[44] D. Amlin, R. Carlisle, S. Kishan, R. Klausmeier, "Evaporative Emissions Impact on Smog Check," August 2001.
[45] "Smog Check II Evaluation," California Inspection and Maintenance Review Committee, June 2000.

Disadvantages of implementing a supplemental GLL check

- Gross liquid leakers are not identified in any systematic fashion using existing manual or electronic (i.e., OBDII) tests.
- Due to the complexity of quantifying total evaporative emissions from vehicles, benefits from repairing fuel leaks are difficult to quantify. Thus, it is difficult to predict evaporative emissions benefits for a fleet as large as that in the *Drive Clean* program using this data. MOBILE6 projections are probably the best possible at this time given the current data limitations.
- Performing evaporative emissions inspections during an I/M inspection increases the time per inspection, potentially decreasing I/M lane throughput and public acceptance. However, California BAR estimates that a visual check for liquid leakers takes less than one minute[46].

Due to the above uncertainties ERG did not attempt to quantify the costs or benefits associated with this option.

6.2.10.5 Recommendation

Due to the large uncertainty in the frequency and emission levels of vehicles with gross liquid leaks, as well as uncertainty in the efficacy of the visual check, we do not recommend implementation of a gross liquid leak check into the *Drive Clean* test at this time. Instead, evaluating data from the recently adopted BAR leak check as it becomes available may be of benefit to the *Drive Clean* program. California and EPA are continuing to conduct studies on randomly procured vehicles to better quantify the emissions from repaired pressure and gas cap defects. While emission level estimates may not be readily available, this additional BAR data should help *Drive Clean* make an assessment of the GLLs in the fleet, approximate expected repair costs, and the overall feasibility of implementing a GLL inspection into the *Drive Clean* test.

6.2.11 Targeting High Emitters

6.2.11.1 Current Program

Currently, high emitting vehicles are identified through their *Drive Clean* test and through Smog Patrol activities. Two additional options are to use remote sensing and additional Smog Patrol inspections to identify high-emitting vehicles, and require that those vehicles report for an off-cycle *Drive Clean* test.

[46] D. Amlin, R. Carlisle, S. Kishan, R. Klausmeier, "Evaporative Emissions Impact on Smog Check," August 2001.

Currently, remote sensing is not used for the *Drive Clean* program. The Smog Patrol, however, is already an integral part of the *Drive Clean* Program and is used to identify vehicles that emit visible smoke or are in a state of disrepair. This is in line with the MOE's risk-based approach for on-road enforcement of Ontario's vehicle emissions standards. The Smog Patrol has requisitioned two mobile dynamometers for use in the near future to enhance their testing capabilities.

6.2.11.2 Benchmark

Several jurisdictions now use vehicle remote sensing devices (RSD) as a tool to improve strategies that reduce on-road emissions. California is in the process of identifying the best way to use this technology as an add-on to their biennial ASM test. Other jurisdictions are investigating the use of RSD for cost-effective application to their unique situation. Arizona and British Columbia perform on-road pullover testing on diesel vehicles, and California performs on-road pullover testing on light-duty gasoline vehicles.

6.2.11.3 Need for Change

A key aspect of the *Drive Clean* program is to find high emitters through the normal biennial test cycle. The repair of these vehicles provides the emissions reductions attributable to the program. As shown in Section 5 and described in Section 6.2.3, vehicles that fail their initial inspection, are repaired, and then pass their reinspection are more likely to become high emitting again before their next biennial inspection (as compared to vehicles which pass their initial inspection). In addition, high emitting vehicles may be operating in the *Drive Clean* area that are not participating in the program, such as vehicles registered in the non-program area of the province, vehicles that are fraudulently registered, or vehicles that may be otherwise avoiding the *Drive Clean* requirements.

6.2.11.4 Analysis of Options

Each of the two options, use of RSD and additional Smog Check activities, are described in the following subsections.

6.2.11.4.1 Using RSD to Target High Emitters

Remote sensing devices (RSD) can quickly measure on-road emissions from large numbers of vehicles operating under real-world driving conditions. RSD vans deployed across the Province could be used to survey the makeup and emissions of the Ontario fleet.

Although RSD testing is still being studied and it is not yet a universally accepted test, it does show promise as an on-road method for monitoring portions of the fleet that otherwise would not be directly tested. In fact, as more I/M programs move toward adoption of OBDII testing, RSD can prove to be helpful in identifying emissions problems not found by OBDII technology.

In Ontario, RSD could be used to independently verify the emissions benefits of the *Drive Clean* program by monitoring readings from vehicles both before and after they have completed the I/M test cycle (through comparison of before/after repair readings for vehicles which initially fail their test but then are retested). Under specific conditions, RSD might also be appropriate for identifying a relatively small number of vehicles very likely to fail their next I/M test (super-emitters). Such vehicles, if found to be subject to the *Drive Clean* program (i.e., registered within the program area), could be sent letters by the Ministry requiring them to appear at the VEC, or any other DCF, for a confirmatory I/M test. Vehicles that fail the confirmatory test would be required to be repaired and retested, just as an "on-cycle" *Drive Clean* participant. RSD could also be used to help determine emission levels and number of vehicles operating in program areas but not participating in the *Drive Clean* program. Out of Province violators could be identified by RSD and issued fines. Fees recovered could be used for various programs, such as a HD diesel pilot study or for retirement incentives for in-province vehicles.

Emissions reduction from RSD identification and repair of non-compliant "off cycle" vehicles can be difficult to quantify, given the variable range of time before a vehicle's next scheduled test. The State of California is in the process of identifying the best way to use this technology as an add-on to their biennial test. Results from the California RSD Pilot project are expected in the fall of 2005. BAR will consider both the timing and the magnitude of the RSD emissions to "flag" the vehicle as a high emitter, as well as exemption of low-emitting vehicles from their next biennial inspection. The final report from the project will present specific recommendations to California about the most cost effective uses for RSD in their decentralized, ASM-based I/M program. We expect that many conclusions drawn in that report will be applicable to the *Drive Clean* program, which is similar in many respects to that of California.

Advantages

- RSD offers a true measurement method for finding off-cycle high-emitters
- RSD offers the ability to gather measurements on a large number of vehicles

Disadvantages

- Although RSD is promising, this technology is not yet universally accepted and it does have some technical issues which may hamper it's widespread viability
- Purchase of equipment and staff labor for data collection and analysis would be necessary for implementing an RSD test program

Costs and benefits for this option were not quantified due to the uncertainty in effectiveness as well as the ultimate scale of the effort.

6.2.11.4.2 Additional Utilization of Smog Patrol to Target High Emitters

In conjunction with their current approach, the use of dynamometers will make the Smog Patrol more consistent with the *Drive Clean* program as the selected vehicles would be measured in a manner similar to the *Drive Clean* test. With the addition of the new test equipment, the Smog Patrol can be used to identify high emitters by evaluating the results of the dynamometer tests and then sending the high emitters to a regular *Drive Clean* test at a DCF or the VEC. The "Form 1" order process may be enhanced for identifying high emitters but it would be more effective if the test requirement were better enforced, and the number of vehicles identified were increased substantially. In addition to their current activities, Smog Patrol could be used for additional activities that are described in Section 6.5.2.

Advantages

- Additional dynamometer testing can help quantify smog-patrol targeting
- Identification of high-emitters can result in appreciable program emission reductions

Disadvantages

- Additional labor and administrative costs would be necessary to implement and enforce off-cycle high-emitter identification and repairs

Costs and benefits for this option were not quantified due to the uncertainty in effectiveness as well as the ultimate scale of the effort.

6.2.11.5 Recommendations

ERG recommends Ontario review the results and recommendations of the California RSD pilot study before developing a RSD program. We also recommend Smog Patrol begin

utilization of the new portable dynamometers to supplement their existing activities, and consider additional options presented in Section 6.5.2.

6.2.11.6 Impact of Recommendations

High emitter identification and repair is fundamentally cost effective, given its preferential focus on the worst polluters. If enough high-emitting vehicles are identified, this option could provide significant emission reductions and health benefits. Consumers would be resistant to this option due to increased inconvenience and repair costs. It would also be less equitable because the highest emitters, which are frequently owned by lower-income motorists, would be targeted more frequently than cleaner vehicles. Costs to the DCO would increase substantially due to the management of the targeting programs and additional test equipment. It would be important to make sure that owners of vehicles identified as high emitters respond to requests by the DCO, participate in confirmatory testing (if needed), and have their vehicles repaired (if needed). The Smog Patrol could use the Form 1 approach to direct identified vehicles for further testing. And with sufficient enforcement these measures could also improve overall program compliance.

6.2.12 Limit the Number of Conditional Passes Granted

6.2.12.1 Current Program

The current *Drive Clean* program is effective at identifying high emitting vehicles. However, approximately 16% of light-duty vehicles that fail their initial *Drive Clean* test (1.6% of all light-duty vehicles tested) are issued a conditional pass for continued operation in the *Drive Clean* area.

6.2.12.2 Benchmark

Ontario (and British Columbia) grant many more conditional passes (16% of initial fails) than in I/M programs in other North American jurisdictions (less than 1% of initial fails). As discussed in Sections 5.2.2 and 5.2.3 of this report, per-vehicle conditional pass restrictions, repair cost limits, and the level of program administrator review/oversight of conditional passes granted can influence the conditional pass issuance rate.

6.2.12.3 Need for Change

By allowing so many vehicles to receive a conditional pass, potential emission reductions from fully repairing these vehicles or permanently removing them from the *Drive Clean* area are lost.

6.2.12.4 Analysis of Option

Limiting the issuance of conditional passes issued by the *Drive Clean* program to one per vehicle lifetime would reduce the number of conditional passes granted and also help ensure that vehicles which receive a conditional pass are either fully-repaired or permanently removed from the program area.

Advantages

- Limiting conditional passes to once per lifetime will reduce the number of on-road high-emitting vehicles
- Verifying repairs helps ensure repairs performed on conditional-pass vehicles are as effective as possible
- Overall general public and media should support this changes, because these vehicles are likely to be high-emitters

Disadvantages

- Limiting conditional passes may encourage some vehicles to avoid program requirements
- Motorists with difficult/expensive to repair vehicles may feel targeted

Quantification of potential costs and benefits for this option was not possible, given the lack of data on repair costs and benefits for conditional pass vehicles coming into compliance with current cutpoint levels.

6.2.12.5 Recommendations

ERG recommends that DCO limit the number of conditional passes to one per lifetime of a vehicle. We also recommend that DCO investigate methods to improve the process of verifying that repairs are actually made, and costs up to the repair cost limit are actually spent, for vehicles that receive a conditional pass. This could be achieved either by specifically auditing a sample of vehicles that received a conditional-pass (by requiring a visual inspection of repairs performed and repair receipts by a Smog Patrol officer) or by requiring that all conditional-passes be verified by a subset of DCFs certified as conditional-pass referee stations.

6.2.12.6 Impact of Recommendations

Limiting the number of conditional passes granted will require that failed vehicles either be fully repaired or permanently removed from the *Drive Clean* area, leading to increased

emission reductions and increased health benefits. This option may encourage some vehicles to avoid program requirements; however, based on historical general I/M program compliance trends, the number of such vehicles is likely to be smaller than the number of vehicles fully repaired or permanently removed. The number of initial tests, test fee revenue for the DCO, or net revenue of the program should not be affected. However, the number of repairs, as well as DCF revenue from repairs, will likely increase. What effect limiting the number of conditional passes will have on the average cost of repairs depends on the disposition of the vehicles that previously received a conditional pass. If most of these vehicles are fully repaired, average repair costs will increase; however, if most of them are permanently removed from the area, average repair costs should be unchanged, or may decrease slightly (since actual repair costs for conditional pass vehicles appear to be higher on average than repair costs for full pass vehicles). Owners of these vehicles will be adversely impacted by this option, whether they pay the additional cost of full repairs or they forego use of the vehicle and permanently remove it from the road. Such impacts can be mitigated somewhat through the adoption of low income repair assistance and/or incentivized accelerated vehicle retirement strategies, which are discussed later in this section.

We anticipate that this option will be extremely cost-effective, since fully repairing conditional pass vehicles, or entirely removing them from service, will result in large and cost-effective emission reductions. We feel this option should be implemented, even if the cost needs to be partially subsidized through a repair assistance program and/or through a vehicle early retirement program. Although owners of conditional pass vehicles are likely to oppose this option, the general public is likely to be supportive, particularly in light of the publicized inequity and negative emissions impact of a multiple conditional pass program. This option should be fairly straightforward to implement, since it removes much of the verification of repairs and repair costs currently required by the *Drive Clean* program, although it would require a verification check to ensure that vehicles receiving a conditional pass have not received one in the past.

6.2.13 Increasing the Repair Cost Limit to Reduce Vehicle Waivers

6.2.13.1 Current Program

In addition to the previous option (limit conditional passes issued to one per vehicle lifetime), another option for reducing the number of conditional passes granted is to increase the repair cost limit. The current program currently requires that CDN $450 (US$350) in vehicle diagnostics and repairs either be made or recommended before a conditional pass is granted.

6.2.13.2 Benchmark

EPA recommended a repair cost limit of US$450 (CDN $575) in 1992 for enhanced IM240 programs. Currently 21 jurisdictions, including British Columbia, have a repair cost limit of US$450 (CDN $575) or higher. Most I/M programs in other jurisdictions require that each conditional pass, or emissions waiver, be verified by a program official before being granted.

6.2.13.3 Need for Change

Since the repair cost limit is lower than that in most I/M jurisdictions, many vehicles are receiving conditional passes that could otherwise be repaired to passing emission levels. Currently there is no procedure in place to verify that reported repairs are actually made, and that reported repair costs are actually spent, for all vehicles that receive a conditional pass.

6.2.13.4 Analysis of Option

This option involves adoption of a higher limit on expenditures required to receive a conditional pass, and also consideration of requiring expenditures for all vehicles which receive a conditional pass to meet the repair cost limit (rather than recommended repairs estimated to meet or exceed the limit). Increasing the repair cost limit might encourage vehicle owners to avoid program requirements. However, in Section 5, we showed that the previous increase in the repair cost limit resulted in a large reduction in the fraction of conditional-pass vehicles, with a large increase in the fraction of full-pass vehicles and only a small increase in the fraction of no-final-pass vehicles.

Drive Clean's previous increase in the repair cost limit (from CDN $200 to CDN $450) resulted in a 50% reduction in the conditional pass rate in each phase of the *Drive Clean* program. Most of the vehicles that would have received a conditional pass appeared to receive a full pass, although there was a small increase in the fraction of no-final-pass vehicles. The fraction of no-final-pass vehicles that were permanently removed from the *Drive Clean* area (as opposed to continued operation within the area) is unknown. However, the drop in the conditional pass issuance rate seen for the prior increase in the RCL is likely to differ from a rate resulting from increasing the RCL from CDN $450 to CDN $600.

Advantages

- Increasing the repair cost limit, requiring "actual" expenditures are at least the repair cost limit, and verifying repair costs are actually spent would help decrease the number of vehicles not repaired to passing levels

Disadvantages

- Increasing the repair cost limit might encourage vehicle owners to avoid program requirements
- Increasing the repair cost limit may be opposed by motorists or be perceived by some as less equitable
- Additional administrative costs commensurate with the level of effort required for repair verification will be incurred

Quantification of potential benefits for this option was not possible, given the lack of data on incremental repair benefits for vehicles spending between the current RCL and the amount proposed.

6.2.13.5 Recommendation

Based on results from the jurisdictional comparison, we recommend raising the repair cost limit to CDN$600 (US$470).

6.2.13.6 Impact of Recommendation

Increasing the repair cost limit will further limit the number of conditional passes granted, and increase emission reductions and health benefits from the program. This option will generally have the same impacts as limiting the number of conditional passes to one per vehicle lifetime, and may also be opposed by motorists or be perceived by some as less equitable. This option may also encourage additional non-compliance as vehicle owners search for ways to register their vehicles without spending more money. In addition, this option will require administrative effort to ensure that the costs claimed in order to obtain the conditional pass were actually paid.

6.2.14 Implement a Vehicle Early Retirement Program

6.2.14.1 Current Program

Although not operated by the Ministry, a vehicle early retirement program entitled Car Heaven is offered in Ontario (and elsewhere) and is operated by the Clean Air Foundation. This program accelerates the retirement of older, high polluting vehicles and promotes a shift from traditional forms of transportation to cleaner alternatives. The *Drive Clean* Office provides in-kind support through packaging and distribution of Car Heaven pamphlets and posters at *Drive Clean* facilities across Ontario.

6.2.14.2 Benchmark

Several programs in other jurisdictions provide motorists a cash incentive for their vehicle if it fails the I/M inspection; the vehicle is then crushed and its materials are recycled to ensure that it is permanently removed from the program area.

6.2.14.3 Need for Change

Developing an in-house accelerated vehicle retirement program can help mitigate the impact on low-income households of reducing the number of conditional passes granted.

6.2.14.4 Analysis of Option

Vehicle early retirement programs, also known as scrappage programs, attempt to reduce emissions by removing vehicles with the highest emissions from the fleet operating in an I/M area. These programs are always voluntary, requiring the consent of the vehicle owner. Programs typically provide monetary incentives to vehicle owners to induce them to retire their vehicles sooner than they normally would. The pollution reductions are estimated based on the retired vehicle's remaining life and emissions, less the emissions generated from a replacement form of transportation (e.g., a "fleet-average" vehicle or a public transit ticket), if any.

The most cost-effective scrappage programs target the highest-emitting vehicles. Determining whether a vehicle is eligible for retirement can be based on a combination of variables, such as the vehicle age, engine type, or emissions control technology, or the results of an emissions test. Each of these criteria has its strengths and weaknesses. Vehicle age is the simplest of all selection criteria. The assumption is that the older a vehicle is, the more it pollutes. Obviously this may not always be the case; a well-maintained older vehicle can actually be less polluting then many newer, poorly maintained vehicles. Using either engine type or the installed emission control technology to choose scrappage candidates is very simple as well. However, these criteria are only useful if there has been a significant change in technology, such as the introduction of a computerized fuel system and a catalytic converter. Using emissions test results is the most complicated of the selection methods, but it is the most accurate in that it helps ensure that the vehicles being replaced are truly high emitters, at least at the time of replacement. "Emissions tests" can consist of a regular I/M inspection, remote sensing measurement, or other "loaded-mode" test that can be used to estimate mass emissions from the vehicle.

Perhaps as important as the emissions of the vehicle at the time of replacement is the expected remaining lifetime of the vehicle. Many retirement programs include criteria that

indicate that the vehicle is in good operating condition, or was actually used in the preceding months. These criteria can include: estimated usage in the preceding years based on the odometer reading from the previous I/M inspection and/or registration data; the capability of the vehicle to be driven both forwards and in reverse; and the physical condition of the vehicle.

Ideally the financial incentive offered for early retirement of a vehicle should depend on its market value and the emission reduction expected from retiring the vehicle, i.e. the current emissions of the vehicle and its remaining useful life. A larger incentive would be offered for vehicles that are expected to make a larger emission contribution if they remained in use. However, estimation of the emission reduction potential of candidate retirement vehicles is not easy or straightforward. There is a concern that a retirement program will merely reward the retirement of vehicles that were not, and could not have been, used, or that would have been retired in the absence of the program.

Two other concerns raised with early vehicle retirement programs that do not affect emissions reductions are reuse of vehicle parts and the equity impacts of the programs. Classic car hobbyists have fought implementation of early retirement programs, arguing that the programs would severely reduce the availability of parts necessary to maintain their classic vehicles. Some programs have developed special provisions to allow the salvaging of key vehicle components before the actual scrappage of vehicles. And advocacy groups have expressed concerns that the incentives offered in retirement programs are not sufficient to provide a similar level of transportation service to the low-income households that tend to own the old vehicles targeted by the program. In addition, there is a concern that an early retirement program will increase the price of used vehicles, further reducing the transportation options available to low-income households. On the other hand, these programs do provide a means of subsidizing program compliance primarily for lower income motorists.

ERG consulted several sources in an attempt to identify past and present accelerated retirement programs in the U.S. and Canada. Based on this review at least eight retirement programs were identified that are currently operating in the U.S. and Canada. The California BAR operates a statewide program as part of their enhanced I/M program, while four California air pollution control districts (in the San Francisco Bay, Los Angeles/Orange County, San Diego, and Santa Barbara areas) operate local programs following guidelines established by the state Air Resources Board. In addition, Oregon has a pilot program that has been operational since September 2000. Finally, British Columbia is currently operating a program. In addition to California, Texas and Illinois have adopted rules for early retirement programs for local air pollution control districts to generate SIP credit, or for stationary sources to generate mobile

source emission reduction credits. Brief summaries of the status of some of the programs currently in operation, along with a discussion of the parts recycling issue, are provided in Appendix B.

Advantages

- Implementing a vehicle early retirement program can reduce the financial burden on households who can't afford to pay for vehicle repairs
- Vehicle early retirement programs can help reduce the number of high-polluting vehicles on the road

Disadvantages

- Proper implementation of a vehicle retirement program would require a fair amount of administrative effort (costs)

Nevertheless, quantification of costs and benefits for such a measure in the *Drive Clean* program were not performed given the uncertainty in vehicle "bounty" values and voluntary participation rates.

6.2.14.5 Recommendation

We recommend that *Drive Clean* institute an in-house vehicle early retirement program, drawing on the experience of similar programs in California and other jurisdictions. The incentives offered by such a program would help mitigate the additional financial burden placed on some motorists from limiting the number of conditional passes granted and increasing the repair cost limit.

6.2.14.6 Impact of Recommendation

Properly implemented, this option would have a positive environmental and health impact, resulting from removing more high-emitting vehicles from Ontario's roads (than are currently "retired" in the existing program). This program would required a fair amount of administrative effort in order to ensure that removing participating vehicles would provide an emissions reduction benefit. Although funds would need to be allocated to support such a program, properly implemented this should provide a relatively cost effective solution for reducing on-road emissions.

6.2.15 Establish a Low Income Repair Assistance Program (LIRAP)

6.2.15.1 Current Program

The *Drive Clean* program does not currently offer a repair assistance program.

6.2.15.2 Benchmark

Low Income Repair Assistance Programs are in operation in California, in Texas, and elsewhere to provide subsidies to qualified low-income motorists for the cost of repairing their vehicles.

6.2.15.3 Need for Change

Low Income Repair Assistance Programs are designed to encourage motorists with limited financial resources to obtain repairs for their failing vehicles. Instituting a low-income repair assistance program can be used to mitigate the impact on low-income households of reducing the number of conditional passes granted.

6.2.15.4 Analysis of Option

A Low Income Repair Assistance Programs provides financial assistance to low-income households in performing emissions-related diagnostic and repair services for vehicles that fail their emissions inspection. Program administrators verify the financial need of potential participants (usually based on household income being at or below an established limit for number of residing individuals), as well as approve (or deny) repairs to be made to vehicles. For eligible participants, these approved repairs are subsidized (generally up to a certain pre-set ceiling). U.S. programs generally use tax documents from the prior tax year, paycheck stubs, or other official income verification documents for demonstration of financial eligibility.

Advantages

- Support of such a program would likely be viewed as socially equitable and could result in repair of vehicles that otherwise might not be repaired

Disadvantages

- Implementation of a LIRAP would required a fair amount of administrative effort (costs)

The benefits of this option are highly uncertain and cannot be quantified at this time. Costs would be proportional to the number of motorists participating in the program.

6.2.15.5 Recommendation

We recommend that *Drive Clean* institute a repair subsidy program, drawing on the experience of similar programs in California and other jurisdictions. This will help mitigate the extra burdens placed on some motorists from limiting the number of conditional passes granted and increasing the repair cost limit.

6.2.15.6 Impact of Recommendation

This option makes the cost burden of an I/M program more equitable, encourages overall compliance with the program, and possibly decreases the number of conditional passes issued by the program. Similarly, LIRAP programs should have relatively positive social impacts, including consumer acceptance. The funds made available through LIRAP programs ultimately go to the DCFs for repair work. Emission reductions (and therefore health benefits) may be increased slightly, to the extent that compliance improves and the number of conditional passes issued is reduced. Vehicles participating in these programs are typically higher emitting than average, so repairs spent on these vehicles should be relatively cost effective. Eligibility for such a program would require DCO verification of family income levels (through tax returns or other means). Additional program oversight would also be needed to assure appropriate repairs are approved and performed.

6.2.16 Improve Program Repair Effectiveness

6.2.16.1 Current Program

The *Drive Clean* Program does not currently employ a repair effectiveness index. Repair facilities and technicians are accredited by the program, and repair information is collected by the Ontario Test Units (OTUs) upon retest.

6.2.16.2 Benchmark

Five of the eleven jurisdictions evaluated have some form of repair effectiveness rating program in place.

6.2.16.3 Need for Change

I/M programs only reduce vehicle emissions when high emitter vehicles that are identified are *effectively* repaired to actually lower emissions, and also if those repairs are durable (low emissions are maintained until the next test cycle and beyond). Implementing a repair effectiveness index for repair DCFs, based on the fraction of vehicles that failed their I/M retest, may be an effective tool in maintaining high program emission reductions.

6.2.16.4 Analysis of Options

Implementing an REI program may be used to improve repair effectiveness. In addition, efforts focused on improving the accuracy of repair data collection will ultimately provide information that can be used to improve the program's repair effectiveness. Implementation of an REI and opportunities for improving the accuracy of repair data that is collected are described in the following subsections.

6.2.16.4.1 Implementing a Repair Effectiveness Index

Implementing a repair effectiveness index for repair DCFs, based on the fraction of vehicles that passed their retest and possibly passed their next biennial I/M test, may be an effective tool in maintaining high program emission reductions. In order to not bias the ranking against garages that generally repair "trouble" vehicles, the index could be normalized to the population of vehicles serviced at each DCF. The REI rankings should be well publicized, perhaps on the *Drive Clean* website. Incentives, such as a "five star" rating, can be provided to encourage DCFs to improve their repairs, and receive a higher REI ranking. In addition, enhancing the existing training program for repair technicians, as well as the existing repair hotline, may bolster the program's repair effectivenessPublication of a repair effectiveness index will transfer revenues from repair DCFs with a low REI to those with a high REI. However, it will require resources to develop a REI methodology, analyze test and repair data in order to create and update REI rankings, and publicize the REI rankings in brochures or on the *Drive Clean* website. It is unclear what impact efforts to improve repair effectiveness will have on non-compliance: test-and-repair DCFs may have an incentive to commit more test fraud in order to improve their REI ranking. On the other hand, if the public responds to the published REI rankings, and patronizes legitimate, high-ranking repair DCFs, this option would use the power of the marketplace to encourage repair DCFs to improve the repairs they perform.

Advantages

- An REI program can be an effective tool in encouraging repair garages to perform necessary and effective repairs efficiently
- An REI program can serve the public by directing motorist to garages shown to perform necessary and effective repairs efficiently

Disadvantages

- REIs can be viewed as inequitable, especially in decentralized programs, where some shops typically repair "trouble vehicles". The shops can be inappropriately "penalized" for their diligence

- REIs can require a fair amount of effort to design and administrate.
- Implementation of a REI program (especially in a decentralized market) can put the program administrators of "recommending" certain garages

The benefits of this option are highly uncertain and cannot be quantified at this time. Costs would be directly proportional to the scale of the effort.

6.2.16.4.2 Improving the Accuracy of Collected Repair Data

Some measures which may be available to help ensure all vehicle repairs and costs are accurately collected are listed below:

- Software on all OTUs should require entry of repair information (types of repairs and costs) *prior* to conducting a retest. Review of repair data showed that repair data was available for all vehicles that received a conditional pass, but repair data was only available for 65% of the vehicles that successfully passed their retest. This suggests that technicians are entering repair data for conditional-pass vehicles after these vehicles have failed the retest, in order to qualify them for the conditional-pass.
- Analysis of repair data indicated some repair data is collected in a format unsuitable for storage/analysis on the VETS. Software changes and certification to ensure proper collection and transmission of repair data between all OTU manufacturers and the VETS would help eliminate the rejection of repair records in an unsuitable format
- Steps may be taken to verify appropriate vehicle repairs are made prior to the issuance of a conditional pass. This is currently reviewed during field audits, but does not involve program administrator scrutiny on a per-pass-issued basis.

Once repair data are completely and accurately collected reported, they can be analyzed to determine the cost-effectiveness of specific repairs, as well as identify pattern repair strategies for particular vehicle makes and models.

Advantages

- Improvement in repair data collection will provide the tool (accurate repair information) needed to bolster and monitor *Drive Clean*'s repair effectiveness and repair durability
- Accurate repair data is a necessary tool in comparing emissions benefit and cost effectiveness of repairs for various types of testing (i.e., OBDII vs. tailpipe)

Disadvantages

- Software changes, certification, and direct DCO intervention during the issuance of conditional passes all require additional resources to implement.

The benefits of this option are highly uncertain and cannot be quantified at this time. Costs would be directly proportional to the scale of the effort.

6.2.16.5 Recommendations

ERG does not recommend that *Drive Clean* adopt a repair effectiveness index (REI) program at this time. There is no evidence that an REI results in more motorists bringing their vehicles to high performing stations, or in more effective and durable repairs being performed, although if this effect exists it would be hard to quantify. Several programs in other jurisdictions have considered, and rejected, implementing an REI. For example, Arizona considered an REI based on Colorado's system, but withdrew the idea because of concerns voice by repair facilities that it would unjustly penalize stations that specialized in older or difficult to repair vehicles. An REI normalized to the population of vehicles serviced at each station could be developed; however, at this point no program includes this normalization in their REI.

ERG does, however, recommend DCO consider changes improve the accuracy of collected repair data. These changes include verifying all OTU software requires DCF technicians to enter repair information before a retest is started; verifying all repair data is collected in a format that is suitable for transmission to and storage/analysis on the VETS; and verifying vehicle repairs, and expenditures on repairs, before a conditional pass is granted.

6.2.16.6 Impact of Recommendations

The measures to improve the accuracy of repair data collection should ultimately allow an increase in the repair effectiveness, emission reductions and health benefits of the program. By improving the effectiveness of repairs, the number of repairs performed, and the average cost per repair, will be reduced. This will reduce repair revenue to DCFs, and benefit motorists. The collection of accurate repair data will allow additional assessment of repair effectiveness of different types of tests. We anticipate that this option will be cost-effective, and will be supported by motorists because it should result in more durable and cost effective repairs. Because the number of passing tests will not be affected, this option will not affect DCO test fee revenue or the program’s overall net revenue.

6.3 HDV Options Assessment

This section focuses on options for the heavy-duty portion of the *Drive Clean* fleet.

6.3.1 Establish a Chip Reflash Program

As part of the Consent Decree with the U.S. Department of Justice, seven diesel engine manufacturers must work with their authorized dealers and other engine rebuild services to install retrofit kits designed to lower NOx emissions for certain diesel engines[47]. Targeted vehicles include those over 8,860 kg manufactured between 1993 and 1999. The kits are designed to modify engine operation under certain transient conditions, lowering NOx emissions significantly. Manufacturers participating in the Consent Decree include Mack, Cummins, Caterpillar, Volvo, Detroit Diesel, Navistar, and Renault. ERG has not determined local market share for these engines, but assumes most of the heavy trucks operating in Canada are made by these manufacturers for the purpose of this analysis.

6.3.1.1 Current Program

The *Drive Clean* program doesn't currently require HD diesel chip reflashing.

6.3.1.2 Benchmark

California has recently made this a requirement of their I/M program. No other state or local jurisdictions require HD diesel chip reflashing.

The US EPA program authorized under the Consent Decree is itself mandatory for the engine manufacturers, although there is no mandatory component of the program that directly impacts drivers and/or owners of the affected engines. Therefore the success of the federal program largely hinges on the voluntary action of engine operators, who must take their vehicles in for rebuild in order for the reflash to occur (discussed below).

6.3.1.3 Need for Change

Significant NO_x emission reductions may be achieved by implementing a program which requires HD diesel fleets subject to the US Consent Decree to have their computerized engine management control chips reprogrammed (reflashed). The benefits of this measure diminish with time as engines with defeat devices are retired from the fleet, or are voluntarily reflashed during their regular rebuild cycle.

[47] See EPA's Office of Regulator Enforcement, Diesel Engine Settlement Information web page, http://es.epa.gov/oeca/ore/aed/diesel/

6.3.1.4 Analysis of Option

Heavy-duty diesel engine manufacturers have developed and are installing retrofit kits designed to modify engine operation under certain transient conditions, lowering NO_x emissions significantly, for heavy-duty diesel engines built between 1993 and 1999. In 2004 trucks in this model year range represented 51% of the heavy-duty diesel vehicles subject to *Drive Clean* testing, and 37% of the entire heavy-duty diesel fleet. The process, termed "reflash", typically just involves reprogramming onboard computer software.

As per Consent Decree requirements, reflash must occur on all affected engines in the U.S. during their regular rebuild cycle. EPA estimates that 90% of all targeted trucks will receive a retrofit kit upon rebuild, and that rebuilds will occur every 5 years for Class 8 trucks (> 15,000 kg), and every 12 years for Class 6 and 7 trucks (8,860 – 15,000 kg).[48]

Therefore it is taking several years for most of the reflash kits to actually be installed. In fact, rebuild rates to date have been extremely slow, with only 6.6% of all affected trucks receiving retrofits through June of 2004[49]. If reflash kit installation can be accelerated, NO_x reductions can be increased significantly. The challenge then becomes developing an effective incentive for truck owners and operators to encourage early participation in the program.

The existing *Drive Clean* testing process provides an excellent opportunity, if all trucks in these weight classes and this model year range are required to obtain a reflash before passing their regular emissions test. The California ARB recently adopted a similar mandatory program.[50] Note however that California's program is currently being challenged in court by the Engine Manufacturers Association (EMA), which contends the program must be voluntary and not mandatory.[51] *Accordingly, ERG recommends waiting for the outcome of this lawsuit before proceeding with a reflash program of its own.* (The following discussion assumes that a mandatory program will be legally enforceable.)

While a reflash itself would not be performed at the DCFs themselves, they should be readily obtainable throughout Ontario.[52] As a result of the Consent Decree, the affected engine manufacturers will provide reflash kits through their Canadian dealers and other engine

[48] *User's Guide to MOBILE6.0*, EPA420-R-02-001, January 2002.
[49] Low NOx Rebuild Program Summary as of June 2004, from Anne Wick, U.S. EPA OTAQ, May, 2005.
[50] http://www.arb.ca.gov/regact/chip04/fro1.pdf
[51] http://www.dieselnet.com/news/0503ema.html
[52] Anne Wick of U.S. EPA indicates that the engine manufacturers are not likely to grant non-engine rebuilders the necessary access to proprietary software information and computer links in order to conduct the reflashes themselves.

rebuilders on the same schedule as their U.S. counterparts.[53] Therefore the reflash kits themselves should be available to these engines on demand, and free of charge, to any engine operator. In addition, installation labor costs incurred by the engine rebuilders will be compensated by the engine manufacturers as well.

In this way costs to truck owners and operators would be reduced, minimizing inconvenience and time out of service.[54] Actual identification of trucks could be done relatively easily as part of the existing PM inspection, simply by visually verifying the presence of the required engine labeling. A more rigorous check would involve verifying the updated code in the engine software, although this would require purchase of vendor-specific scan tools and software packages.[55]

According to manufacturer analysis, on average the reflash does not affect fuel economy significantly. However, in ERG's analysis we assumed a 2% fuel economy penalty based on engineering judgment. (ERG believes there will be some penalty, since the defeat devices themselves were originally installed to improve highway fuel economy.) Even a small increase in fuel consumption can lead to noticeable increases in operation costs for truck owners and operators, with the associated impact directly proportional to kilometers traveled per year. In addition, the possible incremental fuel cost associated with this measure could be somewhat inequitable to locally-registered fleets, as trucks registered outside of the DC area would not necessarily incur the same increase in fuel costs.

Program benefits may be somewhat difficult to verify. Although it should be relatively easy to track the number of retrofit kits installed in an area using manufacturer records, it may be difficult to determine the incremental increase in retrofits over and above the baseline program mandated by the Consent Decree. In addition, we anticipate that a significant percentage of the locally registered heavy-duty diesel truck fleet operates a significant fraction of the time outside of the *Drive Clean* area. Similarly, much of the HDDT VKMT in the area is from out-of-area trucks. Therefore not all of the emission reductions resulting from such a program would actually occur within the target areas although the differential would also be difficult to quantify. Finally, as is true with all accelerated compliance strategies, the incremental benefits from such a program will necessarily diminish over time. However, the extremely low compliance rates to date seem to indicate that significant benefits may extend beyond the time period assumed for completion in the Consent Decree (2009-2010).

[53] http://www.ec.gc.ca/CEPARegistry/documents/regs/OR_resp/sec4.cfm#5
[54] CARB estimates software installation typically takes one hour or less (Levelton 2004, p. 107).

Advantages

- If implemented effectively, a HDDV reflash program could provide substantial cost-effective NO_x reductions in the *Drive Clean* program

Disadvantages

- Owners of reflashed trucks would be slightly penalized, since reflashing temporarily renders the truck out of service and subsequent mileage may be reduced
- Verification of that reflashing has occurred (beyond looking for the "reflashed" sticker) would be difficult and costly
- Emissions benefits from a reflash program could be difficult to quantify

Table 6-22 presents emissions reductions resulting from "reflashing" the computers of heavy-duty diesel vehicles (HDDVs). (Only class HDD7, HDD8A, and HDD8B trucks can be reflashed.) ERG used the MOBILE model to vary the percent of vehicles reflashed using the REBUILD EFFECTS command. (Unlike the estimates for HDV PM benefits, MOBILE modeling of NOx emissions from these vehicles has relatively low uncertainty.) A value of 7% was used for the base case program, corresponding to the current reflash rate in the U.S.[56] ERG then used the default reflash rate in MOBILE to model the implemented option, corresponding to 90% of the estimated percent of Class 6-8b trucks registered in the area and therefore subject to the program. Note that the emission benefits achieved will be distributed well outside the *Drive Clean* area, as a large fraction of these trucks regularly travel outside of the Province as well as the country.[57]

Table 6-22. Emissions Reductions for Heavy-Duty Diesel Reflash (tonnes/yr)

Calendar Year	2005	2010	2015
NO_x	5,729	1,273	736
VOC	0	0	0
CO	0	0	0
NO_x + VOC	5,729	1,273	736

[55] Total capital costs for purchasing all the necessary equipment and software for direct verification of reflash status would be approximately US$5,000.
[56] Low NOx Rebuild Program Summary as of June 2004, from Anne Wick, U.S. EPA OTAQ, May, 2005.
[57] The precise amount of regional VKMT attributable to locally registered trucks is unknown, so just as with the base case PM reduction program, local NOx reductions cannot be determined.

Note that emissions benefits are assumed to drop off precipitously in future years, due to the MOBILE model's assumption regarding engine turnover.

ERG also estimated the likely costs associated with the proposed reflash requirement. Since mechanic time for this repair is billed directly to manufacturers in accordance with the Consent Decree, there are no mechanic costs associated with the reflash procedure. Only driver downtime costs (approximately ½ hour at about $28/hr, from the KPMG 2003 report), and a possible fuel economy penalty were considered. A 2% fuel economy penalty was assumed based on engineering judgment, but we can reasonably assume there will be some penalty, since the defeat devices themselves were originally installed to improve highway fuel economy. The cost factors associated with this calculation are presented in Table 6-23.

Table 6-23 Estimated Costs for Heavy-Duty Diesel Reflash

Driver Time (hrs)	0.5
Cost of Driver time	$349,253
Government Cost	uncertain
Fuel Economy Penalty	2%
Avg Mi/Gal (Class 7 - 8b)	7.0
Mi/Yr (Class 7 - 8b)	34,420
Avg $/liter (Ontario area, May 05)	$0.789
$/yr (fuel penalty)	$1,683,814
Total Annual Cost (2005)	**$2,033,067**

While reflashing (and therefore driver down-time costs) is a one-time event, any fuel economy penalty is a recurring cost. Government costs were not estimated for this option.

Based on the above, a cost effectiveness of $355 per tonne is estimated for implementation of a HDDV reflash program, making it a potentially attractive option.

6.3.1.5 Recommendation

Although there are significant uncertainties, this measure is likely to be highly cost-effective, offering substantial NO_x reductions. Therefore, we recommend that *Drive Clean* require that all 1993 to 1999 heavy-duty diesel vehicles obtain a reflash in order to pass their next emissions inspection. Again, early implementation of this measure is important since the benefits diminish with time, as engines with defeat devices are retired from the fleet, or are voluntarily reflashed during their regular rebuild cycle.

6.3.1.6 Impact of Recommendation

Given the relatively low cost to all groups (engine operators, DCFs, engine rebuilders, and the DCO), and the high levels of NO_x reduction anticipated, accelerated reflash appears to offer a very cost-effective emission reduction (and health benefit) potential. There could be a moderate DCF impact if hardware and software are purchased to directly verify engine reflash status, (which would also require some inspector training), rather than relying on visible labels. Health benefits would be limited to ozone reduction however, since this measure would not impact PM emission rates. Compliance rates are not likely to be affected significantly, although consumer acceptance (in particular fleet operators and commercial drivers) may be somewhat negative due to increased travel and wait time at the engine rebuilder. In addition, the costs associated with possible fuel consumption increases may need to be investigated further though to evaluate possible equity concerns (i.e., relative to trucks registered outside the area which would not be affected by the program.)

Although early reflash programs appear promising, key information pertaining to emissions estimation is not currently available. Specifically, estimates of the fraction of heavy-duty diesel VKMT attributable to locally registered trucks is unknown, and very difficult to estimate. In addition, it is difficult to predict baseline compliance rates with Consent Decree requirements in order to assess incremental program benefits. If this information was obtained, a fleet-specific analysis using the REBUILD EFFECTS command in MOBILE6 could be used to estimate actual emissions changes for the *Drive Clean* area. Nevertheless, if program implementation appears to be inexpensive and convenient it may not be necessary to quantify emission reductions precisely.

6.3.2 Implement Heavy-Duty On-Board Diagnostic (OBDII) Testing

6.3.2.1 Current Program

The *Drive Clean* program does not currently perform OBDII testing on heavy-duty vehicles.

6.3.2.2 Benchmark

Note that while most jurisdictions do not currently require Heavy-duty OBDII testing, Arizona has plans to upgrade their OBDII test system to the Controller Area Network (CAN) protocol and begin OBDII testing of 2004 and newer HDGV and HDDV vehicles (8,501 - 14,000 lbs GVWR).

6.3.2.3 Need for Change

All new heavy-duty vehicles in the U.S. with a gross-vehicle weight rating (GVWR) of 14,000 lb or less (also known as Class 2 and Class 3 heavy-duty vehicles) will be required to have OBDII systems in the near future. These requirements are being phased-in over a period that started in 2004 and will end in 2008. We expect that Canadian trucks will follow approximately the same schedule since this will be most economical for truck manufacturers supplying North America. As of 2005, CW Taylor Consulting estimates vehicles in this GVWR represent about 2% of the VKMT from the Ontario fleet.

Vehicle repairs reported by OBDII systems prevent the excess pollution that would otherwise be allowed to escape into the atmosphere. Diesel OBDII systems will target all criteria pollutants, so a malfunctioning OBDII system could mean higher emissions of HC, CO, PM, and especially NO_x. During the first few years of implementation, new heavy-duty OBDII systems may experience design flaws, but we expect that the systems will operate quite reliably in the mid-term. At that point, carrying out OBDII system testing will serve as an effective method of reducing health and environmental impacts for Ontario.

6.3.2.4 Analysis of Option

The best method to monitor OBDII systems is via an OBDII test, which is similar for diesel and gasoline powered vehicles. OBDII compliant scanners are used to communicate with the vehicle's on-board computer system. The vehicle reports the status of its emissions control components. If any are found to be malfunctioning, the vehicle's problems are diagnosed and repaired.

Given the convenience of an OBDII test and the fact that it addresses all criteria pollutants, performing an OBDII test instead of an opacity test whenever possible may be a reasonable change that could improve the heavy-duty test program. This will require that heavy-duty vehicle test facilities purchase OBDII equipment capable of testing these vehicles and train their technicians accordingly. Although OBDII scanners are fairly inexpensive, training and equipment cost increases could be expected. In addition, integration of OBDII test capability into program OTUs costs significantly more than purchase of OBDII scanners. However, heavy-duty OBDII testing is still viewed as a fairly cost effective measure, which is equitable to motorists.

OBDII-related research that takes place over the next few years should be monitored in order to gain an understanding of OBDII related issues for the aging heavy-duty fleet. If no

significant research has occurred in other jurisdictions by 2006, the Ministry could consider conducting appropriate analyses itself. Such research would attempt to identify appropriate test equipment and test procedures to allow implementing a heavy-duty OBDII I/M program in the 2010 to 2012 timeframe. We expect that by 2010, appropriate OBDII test systems and procedures will be widely available and the OBDII compliant, heavy-duty fleet will have deteriorated enough to warrant the implementation of these tests in Ontario.

Oversight of such a program could require extra DCO oversight, but net revenue would be equivalent, as the OBDII test would be conducted in place of the J1667 opacity test. Compliance impacts would be beneficial, and similar to implementation of a light-duty OBDII test program.

Advantages

- OBDII testing is a convenient, cost-effective way of monitoring criteria pollutant emissions
- As the HDDV fleet converts to OBDII-compliance, OBDII testing could be used to replace the J1667 test

Disadvantages

- Purchase of OBDII test equipment and software changes would be necessary

This option is essentially designed for evaluation with uncertain emission benefits. Costs would be directly proportional to the scale of the test effort.

6.3.2.5 Recommendation

OBDII systems will be required on all new heavy-duty vehicles by 2008. While this technology has a lot of promise, based on experience with OBDII on light-duty vehicles, we recommend monitoring the progress of heavy-duty OBDII testing in other I/M jurisdictions before it is included as part of the *Drive Clean* inspection.

6.3.3 Exempt Additional New Model Year Heavy Duty Diesel Vehicles

6.3.3.1 Current Program

The *Drive Clean* program currently requires annual testing of heavy-duty diesel vehicles (HDDVs) that are more than three model years old (or one year old for resale). No age exemption is offered for older HDDVs.

6.3.3.2 Benchmark

Four of the eleven jurisdictions evaluated conduct HDDV testing. Of those, one has a two-newest model year exemption, one has a three newest model year exemption, one has a five newest model year exemption, and one does not exempt any new model years.

6.3.3.3 Need for Change

Since newer model year HDDVs generally have lower emissions (newer emission control technology as well as less deterioration) than older HDDVs, increasing the exemption "window" could reduce the number of annual HDDV emissions tests with a minimal loss of emissions benefit.

6.3.3.4 Analysis of Option

This option would increase the exemption from the current program policy of two model years old and newer. Exempting additional new model years from the HDDV test program could reduce program costs. Insufficient data currently exists to determine the impacts on emissions reductions from exempting additional HDV model years. However, a higher standard for these vehicles is justified, since they are predominantly commercial vehicles intensively used for profit, and should be extremely well maintained to remain low polluting. Any miscalculations in the design of a model year exemption policy could result in a heavy air pollution penalty. This issue could be further studied in the proposed HDDV pilot study to determine the best approach for arriving at a decision on model year exemptions for this portion of the fleet. The reduction in DCF test fee revenue and consequent program operation fee revenue would be dependent on the number of additional model years exempted. Fleet owners would benefit accordingly. The change in repair revenue would probably be minimal. If implemented, this option would be relatively simple to implement.

Advantages

- Increasing the exemption "window" could reduce the number of annual HDDV emissions tests

Disadvantages

- Insufficient data currently exists to determine the impacts on emissions reductions from exempting additional HDV model years

- HDDVs are predominantly commercial vehicles which accumulate high mileage, so exempting these vehicles can have a larger emissions impact (benefit reduction) than exempting other fleet types (such as LDGVs)

6.3.3.5 Recommendation

Since insufficient data currently exists to determine the impacts on emissions reductions from exempting additional HDV model years, ERG does not recommend changing the existing new model year exemption for these vehicles. This issue can be studied in the proposed HDDV pilot study to determine the best approach for arriving at a decision on model year exemptions (if any) for this portion of the fleet.

6.3.4 Conduct a Pilot Study on Heavy-Duty NO_x and PM Testing

6.3.4.1 Current Program

The *Drive Clean* program currently performs a J1667 opacity test on heavy-duty diesel vehicles within the program area.

6.3.4.2 Benchmark

Other jurisdictions typically either conduct only J1667 testing, or no testing at all, so a pilot study may yield innovative approaches to dealing with NO_x and PM from heavy-duty sources.

6.3.4.3 Need for Change

Changes to current *Drive Clean* testing of heavy-duty diesel vehicles may be of benefit to the *Drive Clean* Program. Previous research indicates that repairs intended to reduce opacity may increase NO_x emissions, especially for older heavy-duty diesel vehicles.

6.3.4.4 Analysis of Option

Investigation into reductions possible through diesel I/M using existing data and research may be of benefit in developing approaches for reduce NO_x emissions from Ontario's heavy-duty diesel fleet. If it is feasible, a diesel I/M program to reduce both NO_x and PM would be an improvement to the current I/M program and would better address the contribution of diesel emissions to ozone formation in Ontario. The DCO could conduct a literature study to assess the possible impacts of an I/M program to reduce both NO_x and PM and to assess the current state of technologies for testing HDDVs in an I/M setting. To assess the impacts of such an I/M program, the literature study should first assess the technological evolution of the fleet in

Ontario. Some new HDDVs are being manufactured with OBDII systems, and others now include NO_x reduction technology (such as exhaust gas recirculation) that, should it malfunction would allow produce higher NO_x emissions. As these technologies become more prevalent in the fleet, at some point (if not already) an I/M program that addresses HDDV NO_x will probably become an important strategy for maintaining air quality standards. The first stage of the literature review would be to identify the point at which such an I/M program change would make sense from an air quality perspective.

As part of that assessment the Ministry should attempt to quantify the impact of HDDVs from outside the jurisdiction. If they are found to significantly contribute to the inventory, legislation should be considered to require their test and repair in both the current I/M program and in any future improvement upon the current program. The investigation into extra-jurisdictional HDDVs would require assumptions be made as to their activity and emissions levels in Ontario. A first-order assessment would simply estimate their activity from travel demand models or previously done traffic studies and would assume that these vehicles are average emitters, as determined by MOBILE6.

As a second stage of the literature study, the DCO should investigate the various technologies available for feasible application to such an I/M program. For example, an I/M test may be possible using Portable Emissions Measurement Systems (PEMS), such as those being used by manufacturers in Federal Conformity tests (as required in the Heavy-Duty Diesel Consent Decree with EPA). Another I/M test option may be a portable dynamometer system developed by Parsons-Australia in a pilot investigation about 6 years ago. They developed both an I/M driving cycle and the system to conduct it upon. Their pilot study also demonstrated the benefits of such a test for both PM and NO_x. Still other options include vehicle remote sensing devices (RSD) at weigh stations and border crossings or ambient air samplers in chase vehicles, like those being used by a team from Aerodyne and the Massachusetts Institute of Technology in studies around North America.

If the literature study determines that diesel I/M to reduce NO_x is warranted, then it may make sense to conduct a pilot investigation into those I/M test technologies deemed appropriate. A pilot study would likely involve comparing the results of the I/M tests on vehicles in Ontario to the results of a standard test. High-emitting HDDVs identified by prospective I/M tests could be repaired and re-tested to assess the effectiveness of the future program. The size of the sample for this pilot project would need to be determined at the time it is designed, but would probably require testing tens or hundreds of HDDVs.

Advantages

- A literature/pilot study could be performed to help develop approaches for reducing NO_x emissions from Ontario's heavy-duty diesel fleet
- A study could also help should quantify the impact of HDDVs from outside the jurisdiction

Disadvantages

- Performing a HDDV test study will consume labor and financial resources

This option is essentially designed for evaluation with highly uncertain emission benefits. Costs would be directly proportional to the scale of the test effort.

6.3.4.5 Recommendation

ERG recommends the DCO conduct a literature study to assess the possible impacts of an I/M program to reduce both NO_x and PM and to assess the current state of technologies for testing heavy-duty diesel vehicles in an I/M setting. As a second stage of the study, the various technologies available for feasible application to such an I/M program could be investigated by conducting a pilot-testing program, if necessary.

6.3.4.6 Impact of Recommendation

Conducting a heavy duty diesel literature and possibly a pilot study would require additional program funds, although, as with the LDD pilot study, this could possibly be partially supported (provision of equipment and testing services) by test equipment manufacturers. Performing this study in conjunction with a LDDV testing pilot study could reduce the total cumulative cost of conducting these studies.

6.4 Improve Compliance and Fraud Prevention

In this section we examine options to improve DCF compliance with *Drive Clean* testing requirements, and options to improve motorist compliance with MTO registration requirements. Although we address these two issues separately, it is not generally possible distinguish the true origin of potentially fraudulent behaviour.

6.4.1 Prevent Test and Repair Fraud

6.4.1.1 Current Program

Like all I/M programs, and in particular decentralized I/M programs, a small number of DCFs in the *Drive Clean* program engage in test or repair fraud. In January 2003, DCO initiated an excellent risk and performance based audit system that uses vehicle test result data to identify DCFs engaging in potentially non-compliant activity, and directs audit resources to toward those DCFs. The risk and performance based audit system currently uses several indicators to trigger a range of audits, such as recordkeeping audits, audits involving gas analyzer calibration checks, or covert vehicle audits. Should a DCF fail an audit (or multiple audits), the DCO has an escalating schedule of actions and remedies, it can impose to bring the DCF into compliance, ranging from issuance of a correction notice to suspension or termination of operations.

6.4.1.2 Benchmark

Most, but not all, of the I/M programs reviewed for this study perform analysis of vehicle test results as a method of identifying potential test fraud. However, insufficient information was obtained from the review to compare *Drive Clean*'s risk and performance based audit system with other types of electronic evaluation systems.

6.4.1.3 Need for Change

The risk and performance based audit system currently used by the *Drive Clean* program appears to be an excellent tool in helping the program allocate auditing resources where they will be of most benefit. The options presented in this section would further enhance the system and allow the program to more thoroughly assess DCF performance.

6.4.1.4 Analysis of Options

The best approach to evaluate the effectiveness of specific triggers is to analyze the fraction of audits that result in DCF suspensions or terminations by the specific indicators that triggered the audit. This will allow DCO to assess which indicators are triggering audits and resulting in DCF suspensions or terminations. DCO can then either remove ineffective indicators or assign higher weights to effective indicators to make the system more efficient (i.e. allocate audit resources to DCFs that will generate DCF suspensions and/or terminations). This is not a simple analysis, as often more than one trigger results in a DCF audit.

While some of the triggers currently being used could be made more effective by some refinements, the DCO should also consider adopting new triggers of test fraud. One such trigger

could be the expected fail rate at a given DCF, based on the distribution of vehicles by type, model year, even make and model that are tested at the DCF. California uses a high emitter profile model that predicts the fail rate of vehicles by model year, make and model based on historical fail rates in the California and Arizona I/M programs (ERG has developed this model). A similar model could be developed based on historical *Drive Clean* test results, to predict the expected failure rate at each DCF based on the population of vehicles tested at that DCF. DCFs with an actual failure rate lower than the predicted failure rate would trip an audit trigger.

California has investigated a sophisticated trigger intended to identify facilities engaging in clean-piping. The analysis is based on the emission test results of all vehicles tested at a testing facility. Clusters of vehicles with statistically similar emissions measurements are identified; stations with large clusters, or a large number of such clusters, are suspected of engaging in clean-piping. California is continuing to examine this trigger/has adopted this trigger.

Advantages

- Assessing, refining, and replacing specific triggers can help improve the effectiveness of the risk-based management system

Disadvantages

- Additional analysis of triggers, and development of new triggers, will require time and resources

The benefits of this option are highly uncertain and cannot be quantified at this time. Costs would be directly proportional to the scale of the effort.

6.4.1.5 Recommendations

We recommend that DCO consider several options to increase DCF compliance. First, DCO should assess in detail the effectiveness of the current indicators used to trigger a DCF audit, and either refine the triggers, or adjust the weights given to each trigger, based on this assessment.

Second, DCO should consider implementing new triggers to predict fail rates and to identify suspected cases of clean piping.

We also recommend the DCO consider allocating more resources to auditing DCFs.

6.4.1.6 Impact of Recommendations

Enhancements to the *Drive Clean* program in order to improve DCF compliance should have positive environmental and health impact. Overall, since the majority of DCFs don't engage in fraudulent behavior, this will further eliminate the inequity resulting from some DCFs "cheating" in order to increase revenue. This may have a negative financial impact on motorists, as motorists may be required to spend more money on repairs for vehicles that would otherwise be fraudulently passed. However, identifying DCFs engaged in fraudulent repair activities would have a positive financial impact on motorists. Social impacts are positive, as compliance enforcement reinforces *Drive Clean*'s policy of fraud prevention. Additional refinements to the electronic auditing system, as well as additional onsite auditing would require additional program resource allocation (negative program financial impact).

6.4.2 Prevent Registration Fraud

6.4.2.1 Current Program

Upon passing an emissions inspection (or upon receipt of a conditional pass), a vehicle is issued a unique Vehicle Inspection Certification Number (VICN). The electronic record containing the VICN is then used during vehicle registration in order to confirm that the vehicle has successfully passed a *Drive Clean* test. However, for various reasons, use of the electronic test record isn't always possible during the registration process. In this scenario, the motorist may use their paper emissions "pass" certificate that was provided during the *Drive Clean* test as a fallback method for registering their vehicle. Use of the paper certificate increases the opportunity for fraudulent registration in the *Drive Clean* program.

However, a registration system change implemented in the second half of 2004 has eliminated the opportunity to use a paper certificate for more than one registration, which appears to be helping reduce paper certificate registration fraud. In addition, ProtectAir has established an interactive website that allows DCO staff to compare the VICNs issued by DCFs for particular emission inspections to those used by MTO to renew vehicle registrations. This is a valuable resource in tracking potential registration fraud.

6.4.2.2 Benchmark

In the *Drive Clean* program, the intent of the paper certificate is to allow motorists to register their vehicle if the electronic test record is not available at the time of their registration. Most I/M programs surveyed rely on electronic test records for verification of a pass inspection result.

6.4.2.3 Need for Change

Analysis of registration data indicates 6% of all *Drive Clean* registration transactions in 2004 were conducted using paper certificates at a MTO facility. Although much of the registration fraud arising out of use of paper certificates should drop significantly as a result of the registration system changes implemented in 2004, use of these paper certificates still presents an opportunity for registration fraud.

6.4.2.4 Analysis of Options

DCO is aware of the potential for motorists to fraudulently renew vehicle registrations using illegitimate paper certificates and other means. Our analysis of registration fraud indicates that steps the DCO took in June 2004 to reduce this practice have reduced the amount of paper certificate registration fraud. However, since most of the identified historical registration fraud in the *Drive Clean* program involves the use of illegitimate paper emissions certificates, DCO should consider eliminating altogether the use of paper certificates to renew vehicle registrations. In addition, our experience with fraud in *Drive Clean* and other programs indicates that a small segment of motorists are persistent in identifying and taking advantage of loopholes in the system. DCO should continue to be vigilant in identifying new methods of registration fraud, and making changes in the program that minimize the number of registration renewals that do not meet program requirements. One way to do this is to regularly analyze the *Drive Clean* test result and MTO registration transaction databases to identify potentially fraudulent behavior, and track progress in curbing such behavior.

Advantages

- A reduction in registration fraud will reduce the number of vehicles driving in program areas that haven't successfully passed a *Drive Clean* test. This will result in positive emission reductions for the *Drive Clean* program.

Disadvantages

- Tightening registration procedures can occasionally inconvenience some motorists who are legitimately trying to register their vehicles. For example, if a motorist passes an off-line test and immediately tries to register the vehicle, the VICN won't be available at registration
- Tightening registration procedures will consume additional administrative resources and will also require further inter-agency coordination, in particular between the DCO and MTO

The benefits of this option are highly uncertain and cannot be quantified at this time. Costs would be directly proportional to the scale of the effort.

6.4.2.5 Recommendation

We recommend the DCO consider eliminating any use of paper certificates in the vehicle registration renewal process. We also recommend the DCO enhance its efforts in reviewing registration data and working with MTO in identifying and eliminating other sources of registration fraud.

6.4.2.6 Impact of Recommendation

Measures to improve DCF and motorist compliance will increase emission reductions (and therefore health benefits), by ensuring that vehicles that should fail their emissions inspection do so, and that vehicles that renew registration pass an emissions inspection. Reducing fraudulent testing practices such as clean-piping will increase the number of retests and repairs performed, and therefore increase both the test and repair revenue of DCFs, as well as increase costs to motorists. It is not clear what effect the additional compliance measures considered here will have on average repair costs. The number of passing tests should increase slightly, for vehicles that previously engaged in registration fraud (but not for vehicles that previously engaged in test fraud). However, additional resources may be needed to improve efforts to identify and correct DCF and motorist non-compliance. We anticipate that these measures will be cost-effective, and will be supported by the majority of motorists (and DCF owners) who follow program requirements. However, this will ooccasionally inconvenience those motorists who are legitimately trying to register their vehicles if an electronic test record is not available. These measures should be easy to implement, but may require additional resources. If successful, these efforts will help prevent DCF and motorist non-compliance.

6.5 Enhance Utilization of Existing Program Components

This section explores improvements that could be made to the *Drive Clean* program through expanded use of existing program components, in particular the Vehicle Emissions Centre (VEC) and Smog Patrol.

6.5.1 Expand Use of VEC

6.5.1.1 Current Program

Currently, the VEC occasionally serves as a *Drive Clean* dispute resolution referee test facility.

6.5.1.2 Benchmark

Most jurisdictions evaluated operate some form of referee / vehicle emissions testing facility.

6.5.1.3 Need for Change

From our current analysis of the *Drive Clean* data, we have concluded that the VEC could be used to enhance the *Drive Clean* program without the purchase of any additional equipment.

6.5.1.4 Analysis of Options

The VEC's current referee activities could be supplemented with repair training, with direct random sampling testing to support program evaluation and improve program test procedures, and also could serve as a hub for investigations and quality assurance testing.

Testing a stratified-random sample of the fleet could help, over time, to illuminate various program issues of concern. A well-designed sample of as small as 0.1% (about 6,000 vehicles) could be considered representative of the fleet, which amounts to testing about 20 vehicles per day for a year. This would likely be an effort comparable to that in British Columbia and Arizona. Utilization of the VEC in this manner could help with DCF performance evaluations, aid in fraud investigation, and help determine if DCFs are conducting improper testing procedures. This information could also be used to help identify and evaluate certain emissions trends among vehicle types, and supplement master lists with vehicle information that could be used to enhance OBDII testing and prevent OBDII test fraud. However, these benefits would need to be weighed with consideration of motorist inconvenience and the cost of possible incentives needed to encourage participation.

We also encourage greater use of the Center for investigative purposes, as well as a variety of additional QA testing services.

Advantages

- Additional use of the VEC will result in program benefits using already-available equipment
- Additional program evaluation information may be gathered through the use of the VEC

Disadvantages

- Additional use of the VEC will consume additional program administrative resources

This option is essentially designed for evaluation with highly uncertain emission benefits. Costs would be directly proportional to the scale of the test effort.

6.5.1.5 Recommendations

From our current analysis of the *Drive Clean* data, we have concluded that the Vehicle Emissions Center (VEC) is underutilized. We suggest that the VEC could be used as a facility for direct random sampling to support program evaluation testing, a center for technician repair training, a consumer complaint and assistance clearinghouse, and a hub for investigations and quality assurance testing.

6.5.1.6 Impact of Recommendations

Costs of operating a facility of this type would require additional testing and analysis resources, and thus cost-effectiveness is difficult to ascertain at this point. *Direct* Environmental and health impacts would be negligible, as would financial impacts to DCFs and motorists. However, potential social benefits of expanded use of the VEC are notable, as well as program improvement possibilities which could result in longer-term indirect environmental and health benefits.

6.5.2 Expand Use of Smog Patrol

6.5.2.1 Current Program

The Smog Patrol currently identifies vehicles that emit visible smoke or are in a state of disrepair: Such vehicles then either receive a fine, or receive a notice to report for an off-cycle test at a DCF. This is in line with the Ministry's risk-based approach for on-road enforcement of Ontario's vehicle emissions standards. The Smog Patrol has also requisitioned two mobile dynamometers for use in the future to enhance their testing capabilities.

6.5.2.2 Benchmark

Several programs in other jurisdictions use a random roadside testing program for heavy-duty vehicles; however, none use a similar program for light-duty vehicles (California runs a voluntary roadside testing program for research purposes only; Connecticut, Georgia, and Texas

are using, and Virginia is considering using, remote sensing measurements to call in suspected high emitting vehicles for off-cycle testing).

6.5.2.3 Need for Change

Smog Patrol's current activities could be enhanced in such a way as to provide additional value with minimal cost impact to the program.

6.5.2.4 Analysis of Options

In conjunction with their current approach, the use of dynamometers will make the Smog Patrol more consistent with the *Drive Clean* program as the selected vehicles would be measured in a manner similar to the *Drive Clean* test. With the addition of the new test equipment the Smog Patrol can be used to identify high emitters by evaluating the results of the dynamometer tests and then sending the high emitters to a regular *Drive Clean* test at a DCF or the VEC. The "Form 1" order process may be enhanced for identifying high emitters but it would be more effective if the test requirement were better enforced, and the number of vehicles identified were increased substantially. In addition to their current activities, Smog Patrol could also be used for the following activities:

- Smog Patrol personnel could be stationed outside DCFs to identify high emitters. These covert station checkups could be triggered through DCF test record analysis revealing potential test fraud. This, along with current covert audit activities, could help in developing data against stations engaged in test fraud.
- Smog Patrol personnel could also perform more follow up compliance activities resulting from audits, such as ensuring that vehicles that were not properly tested initially are brought back to a facility for retesting under controlled conditions.
- Smog Patrol personnel could assist with the effective implementation of program options, such as the implementation of GLL inspections. However, implementing activities such as these could require additional Smog Patrol personnel be added to the program.
- Smog Patrol could be used for enhancing an OBDII test program, through the use of two OBD II scanners that could be used to target potential high emitters during roadside inspections.
- Smog Patrol personnel could develop methodologies for conducting on-road surveys to be used for quantifying the number of vehicles operating in program areas but not participating in the *Drive Clean* program. Equipment such as digital cameras with plate recognition software, such as that used for RSD testing could be utilized.

- Smog Patrol could be used in assessing what is the best option to pursue for LDD testing (if it can be done roadside) as well as possibly helping to estimate PM and NO_x emission benefit from LDD test program changes

Advantages

- Additional use of Smog Patrol personnel and equipment could help improve program effectiveness by identifying off-cycle high emitters
- Additional use of Smog Patrol personnel and equipment could help improve DCF compliance
- Other program enhancements, such as GLL inspections, OBDII testing, on-road surveys, and special test studies could be implemented using Smog Patrol personnel and equipment

Disadvantages

- Enhancement of the Smog Patrol's activities would require additional money and personnel resources

This option is essentially designed for evaluation with highly uncertain emission benefits. Costs would be directly proportional to the scale of the test effort.

6.5.2.5 Recommendations

We recommend that the Smog Patrol's existing compliance and enforcement activities be expanded as described above.

6.5.2.6 Impact of Recommendations

Expansion of the role of Smog Patrol would likely have a positive environmental and health impact. DCF financial impact could be slightly positive, as vehicles are directed for "off-cycle" retesting. Similarly, motorist financial impact would be negative, as motorists would be required to receive more *Drive Clean* tests than they currently receive. Social impacts would probably be mixed, in that the program would be removing some non-compliant vehicles from the jurisdiction, although owners of these non-compliant vehicles would undoubtedly feel targeted. Some of the enhancements to Smog Patrol's activities would require additional money and personnel resources. These additional activities would help the *Drive Clean* program reinforce its efforts to prevent fraud.

7.0 Key Findings and Recommendations

Smog and PM are serious health issues in Ontario, particularly in the southern portion of the province. Motor vehicles (i.e., passenger cars, light-duty trucks, and heavy-duty trucks) have been identified as the largest domestic source of NO_x, VOC, and PM emissions in Ontario. Motor vehicles also emit significant quantities of other pollutants that adversely affect air quality (e.g., carbon monoxide, benzene, and other toxic compounds) and climate change (i.e., carbon dioxide). To reduce motor vehicle emissions and their associated health and air quality effects, Ontario has adopted a three-pronged approach focusing on cleaner fuels, cleaner vehicles, and improved vehicle maintenance. I/M programs such as Ontario's *Drive Clean* program are the centerpiece of strategies to reduce emissions from mobile sources throughout North America.

ERG is under contract to the Ontario Ministry of the Environment to conduct a review of the *Drive Clean* program. The purposes and objectives of the *Drive Clean* program review study include:

- Evaluation of the *Drive Clean* program's current and future environmental, economic, and social costs and benefits.
- Evaluation of the *Drive Clean* program's effectiveness in achieving its goals and objectives
- Comparison of the *Drive Clean* program relative to other decentralized I/M programs.
- Development of future program improvement options.
- Assessment of future program improvement options leading to recommendations for maximizing the program's effectiveness.

ERG has conducted independent analyses of the various elements of the *Drive Clean* program, using the emission test results for all vehicles tested in the program since its inception through 2004. In addition, we have reviewed several other reports and analyses conducted by the *Drive Clean* office, its contractors and auditors. We have also conducted a jurisdictional scan of other I/M programs around the country to compare, contrast, and provide input for change. Also, we have conducted extensive mobile source emissions modeling to estimate emissions reductions in 2005, 2010, and 2015 from the current I/M program and from some of the options we are recommending. In conclusion, we provide a summary of the recommended improvements to the *Drive Clean* Program.

Results Summary

Our detailed statistical, financial, and modeling analysis has concluded that the *Drive Clean* Program in Ontario is reducing smog causing pollutants. The Light Duty program is reducing emissions at a cost-per-tonne level comparable to that reported for similar programs. The Heavy Duty program is more difficult to assess due to the lack of recent data on the "real world" emissions from Heavy Duty vehicles. We have drawn our conclusions from previous work conducted in Ontario and other studies conducted in North America. Our recommendations for enhancing both the Light and Heavy Duty Programs are summarized later in this section.

Table 7-1 shows the emissions reductions from the light-duty vehicles for the current *Drive Clean* program based on Stewart Brown Associates (SBA) and ERG MOBILE6.2C modeling. The SBA estimates are for the 1999-2003 time frame and ERG estimates are for 2005, 2010, and 2015. The table shows that significant emissions reductions are being achieved by the program.

Table 7-1. Historical and Projected Annual Emissions Reductions from Light-Duty Vehicles Due to the *Drive Clean* Program (in metric tonnes/year)

	Year	HC (tonnes/yr)	CO (tonnes/yr)	NO_x (tonnes/yr)	HC+NO_x (tonnes/yr)	HC+NOx+CO/7 (tonnes/yr)
Historical (SBA, 2005)	1999	3,331	45,325	1,741	5,072	11,547
	2000	7,547	90,939	3,434	10,981	23,972
	2001	11,282	120,817	4,617	15,899	33,159
	2002	17,783	239,525	8,437	26,220	60,438
	2003	17,529	199,989	5,591	23,120	51,690
Projected (ERG, 2005)	2005	7,502	174,662	7,371	14,873	39,825
	2010	6,647	159,456	6,390	13,037	35,816
	2015	6,225	153,732	6,514	12,739	34,701

Note that ERG's modeling of base case HC emission reductions from the *Drive Clean* program in 2005 are substantially less than those reported for 2003. One reason for this difference is that ERG's modeled reductions using MOBILE are based on national emission factors and assumptions regarding the effectiveness of I/M programs, whereas the SBA estimated reductions are based on reductions in mass-based emissions from a sample of vehicles tested and repaired in British Columbia.

Regardless of any difference between these two calculation methods, it is clear that the current program is producing substantial reductions in ozone precursor emissions (primarily HC and NO_x), as well as large reductions in CO emissions.

Based on ERG's research we can conclude that the $/tonne estimates shown above are roughly in line with those calculated for other I/M programs in North America (see Section 4.5 and Table 4-14). However, the exact reasons for any differences with other programs cannot be determined without detailed comparisons with other program studies.

The discrepancy between the historical and projected 2005 cost-effectiveness estimates is due to the different emission reduction calculation methods used, as discussed above. ERG performed a sensitivity analysis for the historical program, evaluating the potential impact of different cost assumptions. First, ERG estimated the costs for both up-front equipment purchase and monthly lease, both arrangements being common in the testing industry. ERG also used different sources of information to estimate repair costs – one scenario developed bottom-up estimates from technician labor rates, repair times, and parts costs (from KPMG), while another utilized reported repair costs from the Vehicle Emissions Test System Database (VETS). The resulting $/tonne values ranged from $3,275 for an up-front equipment purchase and bottom-up repair cost estimates, to $4,125 for a monthly lease and repair costs from the VETS. The resulting range is relatively tight, lending confidence to our general conclusions regarding cost-effectiveness.

Table 7-2. Cost Effectiveness for Light Duty Program ($/tonne/HC+$NO_x$+CO/7)

SBA Basis	M6.2C Base Case		
Historical	**2005**	**2010**	**2015**
$3,387	$4,640	$5,414	$5,882

For the remaining evaluations, ERG assumed DCFs would lease their equipment, based on our general familiarity with the industry. ERG also has reservations regarding the accuracy of the repair cost data reported in the VETS, and has used bottom-up repair costs instead.

- There was too much uncertainty in estimated emission reduction data to estimate the cost effectiveness of the heavy-duty vehicle program. In contrast to LDV, there is no US EPA model to project with rigour future HDV emissions reductions from I/M programs. There is a lack of accurate cost parameters (e.g. difficult to determine average cost of test and repairs) on HDV to determine cost per tonne of emission reduction. In addition, there is no established cost-effectiveness benchmark for HDV I/M programs. Lastly, there is a lack of comparative jurisdictions with a mandatory periodic HDV I/M program such as

Drive Clean. For these comparative jurisdictions, there is a lack of information on their HDV programs.

As is the case for other jurisdictions, for Heavy Duty Vehicles, the emissions reductions estimates for the *Drive Clean* Program are based on less robust modeling methodologies as compared with Light Duty estimates. These reduction estimates are shown in Table 7-3.

Table 7-3. PM Emission Reductions from Heavy-Duty Vehicles

Year	Tonnes / Yr
2000	415
2001	483
2002	193
Total	**1,091**

Source: GW Taylor Consulting

Relative Effectiveness of *Drive Clean* Program Measures

In order to better understand the relative effectiveness of the measures contained in the *Drive Clean* program, ERG undertook an assessment of other I/M programs in the U.S. and Canada. This jurisdictional scan included two levels of review of I/M programs: review of the general characteristics of all I/M programs, and more detailed analysis of programs either with many common features with *Drive Clean* (California, British Columbia, Georgia, Texas and Virginia) or generally regarded as model programs (Arizona and Colorado). These reviews were used to identify strengths and weaknesses in the current *Drive Clean* program, and to identify "best in class" strategies in use elsewhere.

Drive Clean's overall compliance efforts have been effective. A detailed system designed to trigger audits is in place, and the program conducts approximately 4,500 annual overt and covert audits. DCO has worked diligently to suspend or terminate noncompliant DCFs, and close compliance loopholes when found. A system of compliance of this magnitude is not common among other jurisdictions.

On-road enforcement, via the Smog Patrol program, is also an area where *Drive Clean* stands out. Very few jurisdictions use on-road testing to identify high emitters for off-cycle I/M testing. California conducts roadside pullover ASM tests on approximately 2,000 vehicles per year; however, although motorists are required to pull their vehicle over when flagged by a highway patrolman, they can decline to submit their vehicle to a roadside visual or emissions inspection. California uses the roadside pullover data only for program evaluation purposes. Phoenix, AZ had a large-scale remote sensing high emitter identification program between 1995

and 2000; high emitter vehicles identified by remote sensing measurements were supposed to report for an off-cycle I/M inspection. However, the program was ineffective for a variety of reasons, and was eventually terminated. Other states are using remote sensing measurements to call in suspected high emitting vehicles for off-cycle testing.

However, while many facets of the program are notable for their overall effectiveness, there is still room for improvement in some areas. Recommendations for enhancement of the program, along with discussion of related program design features of other jurisdictions, are discussed below.

Detailed analysis of the relative effectiveness of the *Drive Clean* program, including comparison with programs in other jurisdictions, is provided in Section 6. The full jurisdictional scan conducted for the analysis in provided in Appendix C of this report.

Environmental and Health Effects

The *Drive Clean* program is providing significant improvements to regional and local air quality by reducing the health impacts associated with exposure to ground-level ozone, carbon monoxide, toxic chemicals such as benzene, and fine particulate matter from diesels, The direct environmental and health impacts attributable to the *Drive Clean* program are difficult to determine, however, requiring complex and highly uncertain exposure and health assessments. Nevertheless, the program's significant reductions are expected to decrease both the mortality and morbidity impacts associated with local and regional air pollution as a whole. Other environmental benefits include potential improvements to visibility (from PM) and reduced damage to crops (from PM and NO_x).

At this time there is some evidence that the light and heavy-duty vehicle components of the *Drive Clean* program may produce slight benefits in vehicle fuel economy. However, these benefits are expected to be on the order of less than 1% and were not explicitly quantified for this study. Accordingly, there may be a small but unquantified reduction in greenhouse gas (CO_2) emissions associated with the program.

Social Impacts

The introduction of the *Drive Clean* program has had several hard to quantify, but quite real social impacts across the region, all of which should be considered for the long-term success of the program. These include impacts on consumer protection, the perceived equity of the program, and motorist acceptance of the program in general.

A formal assessment of social impacts would require extensive surveys of Ontario area motorists, which is beyond the scope of this assessment. Nevertheless some general observations can be made regarding the social impacts of the *Drive Clean* program. First, the certification process for repair technicians, along with the phase in of higher repair cost limits and tighter ASM emissions cutpoints, were intended to adequately train repair technicians over time, and minimize opportunities for fraudulent repairs.

The relatively low repair cost limits, and the provision allowing for unlimited conditional passes over time, tends to ease the burden of the program on lower income motorists, who tend to own higher emitting vehicles. The recent increase in the repair cost limit (and additional proposed changes – see below), tends to increase the financial impacts on lower income participants, and may be perceived as inequitable. On the other hand, requiring those vehicles with the highest emissions to be repaired may be viewed as equitable by some, consistent with a "polluter pays" approach to emission reduction.

Finally, overall motorist acceptance of the program depends on a host of factors, including test fees, fail rates, repair costs, inconvenience, and the perceived need for and effectiveness of the program itself, as well as the equity and consumer protection issues noted above. Program adjustments designed to increase consumer convenience, decrease out of pocket test and/or repair costs, would have a positive impact on motorist acceptance in the future.

Recommendations for Program Enhancement

In the current evaluation of the program the ERG team considered many new approaches to improve the effectiveness of the program, including potential emissions reductions, cost effectiveness, social and other impacts of the program. For this analysis ERG performed detailed analyses of the *Drive Clean* test results since program inception (in 1999) through 2004 to identify both strengths and weaknesses of the current program. These analyses included assessment of the following aspects of the program:

- model years tested
- types and classes of vehicles tested
- program area
- test method (ASM, including preconditioning requirements; OBDII scan; curb idle)
- test fees charged
- cutpoints used

- repair effectiveness
- repair cost limits for the granting of conditional passes
- test frequency
- DCF compliance program
- test/repair fraud
- registration fraud
- on-road enforcement program
- investigation program
- public acceptance
- program revenue neutrality

Options to improve *Drive Clean* were selected based on these analyses. Selected options were restricted to measures that have already been successfully adopted in other programs, or could be carefully evaluated using existing information.

For each of the options thus identified, a technical evaluation was performed to assess emission reduction potentials and costs. When sufficient information was available for a particular option, either through actual performance evaluations or modeling, we made quantitative estimates of mass emission reductions and cost-effectiveness; more detail on these estimates is included in Section 4 of this report. For other options qualitative assessments were made of emission reductions and cost-effectiveness.

In addition to emission reductions and costs, each option was evaluated in terms of several discrete evaluation criteria, relative to the current *Drive Clean* program:

- Environmental Impact
- Health Impact
- Financial Impacts
- Cost Effectiveness
- Social Impacts
- Program Impacts
- Compliance Impact

Below we summarize our recommendations for enhancements to the *Drive Clean* program to make it more effective in reducing on-road vehicle emissions.

Light Duty Vehicle Program

Exempt Two Additional New Vehicle Model Years (i.e., 4 and 5 year old vehicles)

Based on our survey of new model year exemptions in other jurisdictions, and our estimate of the emission reductions from exempting the two newest model years currently tested under the program, we recommend that *Drive Clean* consider exempting two additional model years (that is, exempting 5 year old and newer vehicles, as opposed to the current 3 year old and newer exemption). We estimate that these two model years account for about 22% of the vehicles in the program, but account for only 2% to 3% of emission reduction potential. We do not recommend exempting an additional two model years (that is, 6 and 7 year old vehicles), as no other I/M programs exempt so many model years, and exempting these vehicles from the program would have an unacceptable reduction in program emissions benefits. We recommend retaining *Drive Clean*'s existing "test on resale" requirement.

End 20-Year Exemption for Older Vehicles (test 1981 and newer vehicles)

Currently, the *Drive Clean* program has a rolling model year exemption for 20-year-old and older vehicles. We recommend ending the rolling-year exemption, and test 1981 and newer vehicles. Eight other jurisdictions have a rolling model year exemption for older vehicles (with either 25- or 26-year-old and older vehicles exempted). Twenty-three (23) jurisdictions exempt vehicles older than a specific model year (all but three of these test vehicles older than 1980), while three jurisdictions test vehicles of all ages. Although there are relatively few numbers of these vehicles and they are not driven as many kilometres, they represent the greatest emission reduction potential per vehicle tested.

Require Annual Testing for Vehicles that Failed the Initial Emissions Test of Their Previous *Drive Clean* Inspection

40% of vehicles that failed their previous initial emissions inspection, and passed a retest, failed their next initial inspection. Based on analysis of vehicles that received an off-cycle test, much of this emissions increase between I/M test cycles occurs shortly after the vehicle passes its retest on the first cycle. We recommend that *Drive Clean* consider requiring all vehicles that fail their inspection be tested one year later, in order to encourage more durable repairs of these vehicles, and to reduce the annual emissions from those vehicles not found to have received durable repairs.

Implement On-Board Diagnostic System (OBDII) Testing for 1998 and Newer Gasoline Vehicles

For 1998 and newer vehicles, we recommend retaining the ASM test but replacing the post-ASM curb idle test with an OBDII test (vehicle must pass both). California tests all 1996 and newer vehicles using a 2-mode ASM test and an OBDII test. We recommend this more onerous OBDII/ASM test primarily based on three reasons:

- ASM equipment already exists in Ontario;
- Retaining the ASM test will provide a mechanism to monitor the accuracy of OBDII systems, as well as estimate the cost effectiveness of repairing individual vehicles that fail an OBDII test, as vehicles accumulate high mileage and age; and
- Several states in the US (including California, Colorado, and Oregon) have seen evidence of vehicles with high tailpipe emissions that have passed the OBDII test. This may be evidence of potential errors of omission (i.e. false passes) with certain OBDII systems.

In addition, there are uncertainties regarding OBDII performance in high mileage and/or old vehicles and in LEV, ULEV and SULEV vehicles. Retaining the ASM test allows the estimation of emission reductions from OBDII I/M testing.

Ensure Vehicles Undergoing ASM Testing are at Operating Temperature

We recommend that *Drive Clean* consider requiring a 90-second preconditioning period year-round. Analysis of data collected on a random sample of vehicles could be performed in order to quantify the effect of preconditioning time and ambient temperature on false HC and CO failures and false NO_x failures. Alternatively, DCO could require that all vehicles that fail the initial test receive a second chance test (regardless of emission levels at the time of the first chance fail). This would result in any vehicle that falsely fails the initial test due to insufficient preconditioning would receive a second chance test.

Perform a LDD Test Pilot Program

Due to the lack of information regarding PM and NO_x emissions from LDDVs in the *Drive Clean* fleet, we recommend conducting a LDDV pilot study, perhaps in conjunction with a HDDV pilot study, in order to gather information necessary for developing program improvements. Our review indicates the current LDDV test program may not be providing valuable emission reduction benefits.

Limit the Number of Conditional Passes Granted

Ontario and British Columbia are the only two jurisdictions that allow an unlimited number of conditional passes per vehicle. As a result, the number of conditional passes issued in these jurisdictions is much higher than in other I/M programs. We recommend that DCO limit the number of conditional passes to one per lifetime of a vehicle. We also recommend that DCO investigate methods to improve the process of verifying that repairs are actually made, and costs up to the repair cost limit are actually spent, for vehicles that receive a conditional pass.

Increase the Repair Cost Limit (RCL)

We recommend raising the RCL to CDN$600. EPA recommended a repair cost limit of US$450 (CDN$575) in 1992 for enhanced IM240 programs; currently 21 jurisdictions, including British Columbia, have a repair cost limit of US$450 or higher.

Provide Repair Subsidies for, and Incentives for Early Retirement of, Vehicles that Fail the *Drive Clean* Test

Several programs in other jurisdictions provide motorists a cash incentive for their vehicle if it fails the I/M inspection; the vehicle is then crushed and its materials are recycled to ensure that it is permanently removed from the program area. Similarly, several programs provide subsidies to qualified low-income motorists for the cost of repairing their vehicles. We recommend that *Drive Clean* institute a repair subsidy program and an in-house vehicle early retirement program, drawing on the experience of similar programs in California and other jurisdictions. These programs will help mitigate the extra burdens placed on some motorists from limiting the number of conditional passes granted and increasing the repair cost limit.

Improve Program Repair Effectiveness

ERG recommends DCO consider changes improve the accuracy of collected repair data. These changes include verifying all OTU software requires DCF technicians to enter repair information before a retest is started; verifying all repair data is collected in a format that is suitable for transmission to and storage/analysis on the VETS; and verifying vehicle repairs, and expenditures on repairs, before a conditional pass is granted.

Heavy-Duty Vehicles

Require Engine Chip Reflash for Heavy-Duty Vehicles as Part of *Drive Clean* Inspection

Heavy-duty diesel engine manufacturers have developed and are installing retrofit kits designed to modify engine operation under certain transient conditions, lowering NO_x emissions significantly. The process, termed "reflash", typically involves a simple reprogramming onboard computer software. If it is determined that reflash requirements can in fact be mandated (see Section 6.3.1.4), then we recommend *Drive Clean* require all 1993 to 1999 heavy-duty diesel vehicles obtain a reflash in order to pass their next emissions inspection

Conduct a Pilot Study on Heavy-Duty NO_x and PM Testing

Previous research indicates that repairs to reduce opacity are likely to increase NO_x emissions, especially for older heavy-duty diesel vehicles. ERG recommends the DCO conduct a literature study to assess the possible impacts of an I/M program to reduce both NO_x and PM and to assess the current state of technologies for testing heavy-duty diesel vehicles in an I/M setting. As a second stage of the study, the various technologies available for feasible application to such an I/M program could be investigated by conducting a pilot-testing program, if necessary.

Other General Recommendations

Prevent Test and Repair Fraud

We recommend that DCO consider several options to increase DCF compliance. First, DCO should assess in detail the effectiveness of the current indicators used to trigger a DCF audit, and either refine the triggers, or adjust the weights given to each trigger, based on this assessment. Second, DCO should consider implementing new triggers to predict fail rates and to identify suspected cases of clean piping.

Prevent Registration Fraud

DCO is aware of the potential for motorists to fraudulently renew vehicle registrations using illegitimate paper certificates and other means. Our analysis of registration fraud indicates that steps the DCO took in June 2004 to reduce this practice have reduced the amount of paper certificate registration fraud. Since most of the identified registration fraud in the *Drive Clean* program involves the use of illegitimate paper emissions certificates, ERG recommends the DCO consider eliminating the use of paper certificates to renew vehicle registrations. In addition, our

experience with fraud in *Drive Clean* and other programs indicates that a small segment of motorists are persistent in identifying and taking advantage of loopholes in the system. We recommend the DCO remain vigilant in identifying new methods of registration fraud, and making changes in the program to minimize the number of registration renewals that do not meet program requirements. One way to do this is to regularly analyze the *Drive Clean* test result and MTO registration transaction databases to identify potentially fraudulent behavior, and track progress in curbing such behavior.

Expanded Use of VEC

From our current analysis of the *Drive Clean* data, we have concluded that the Vehicle Emissions Center (VEC) is underutilized. We suggest that the VEC could be used as a facility for direct random sampling to support program evaluation testing, a center for technician repair training, a consumer complaint and assistance clearinghouse, and a hub for investigations and quality assurance testing.

Expanded Use of Smog Patrol

The Smog Patrol is an integral part of the *Drive Clean* Program. It is currently used to identify vehicles that emit visible smoke or are in a state of disrepair. We recommend an expanded role for the Smog Patrol in identifying high emitters out of the regular biennial I/M cycle, DCF compliance support, and enforcement.

Monitor I/M Aspects in other jurisdictions

We also recommend the monitoring of the following program elements based on developments in other I/M jurisdictions:

- Use of remote sensing devices to augment the *Drive Clean* Program
- Enhanced evaporative emissions inspection to identify and repair gross liquid leakers
- Use of OBDII devices on heavy duty vehicles.

Table 7-4. Summary of Reductions and Cost Effectiveness for I/M Options

Exempt MYrs 4 and 5				**Test 1981+ MYrs**			
Emission Reductions				Emission Reductions			
	2005	2010	2015		2005	2010	2015
NOx	-106	-88	-98	NOx	1,282	914	357
HC	-115	-137	-114	HC	2,558	908	449
CO	-3,389	-2,715	-2,937	CO	39,515	17,249	9,302
HC+NOx+CO/7	-705	-613	-632	HC+NOx+CO/7	9,485	4,287	2,135
Cost Effectiveness				Cost Effectiveness			
$/tonne HC+NOx+CO/7 (Incremental)	$11,986	$15,510	$15,804	$/tonne HC+NOx+CO/7 (Incremental)	$403	$1,114	$1,621
$/tonne HC+NOx+CO/7 (Whole Program)	$4,501	$5,241	$5,699	$/tonne HC+NOx+CO/7 (Whole Program)	$3,825	$4,954	$5,635
OBDII (98+ vehicles)				**HD Reflash**			
Emission Reductions				Emission Reductions			
	2005	2010	2015		2005	2010	2015
NOx	252	824	1,567	NOx	5,729	1,273	736
HC	518	1,389	2,395	HC	0	0	0
CO	3,065	9,747	16,869	CO	0	0	0
HC+NOx+CO/7	1,208	3,605	6,371	HC+NOx+CO/7	5,729	1,273	736
Cost Effectiveness				Cost Effectiveness			
$/tonne HC+NOx+CO/7 (Incremental)	$16,488			$/tonne NOx (Whole Program)	$355		
$/tonne HC+NOx+CO/7 (Whole Program)	$4,888						
Dual OBDII/ASM Testing							
Emission Reductions							
NOx	637	1,905	3,194				
HC	988	2,232	3,429				
CO	14,523	43,181	68,167				
HC+NOx+CO/7	3,699	10,305	16,362				
Cost Effectiveness							
$/tonne HC+NOx+CO/7 (Incremental)	$10,350						
$/tonne HC+NOx+CO/7 (Whole Program)	$4,745						

Table 7-4 presents a synopsis of emission reductions and cost-effectiveness for several of the options analyzed. In summary, increasing the number of model years under exemption from 3 to 5 would incur a cost savings and be popular with motorists, but would increase the general level of atmospheric pollutants.

Extending testable model years back to 1981 would impact a large number of motorists unaffected by the current program, and would increase costs from both additional initial tests and a dramatic increase in retests for vehicle greater than 20 years old. Also, note that the cost per tonne increases from 2005 to 2015 as fleet vehicle standards drop.

Implementing a heavy-duty diesel reflash program would be extremely cost-effective. There is almost no truck downtime in such a program, and costs are quite low, although truck fuel economy may suffer somewhat.

Anticipated Impact of Recommended Options

Nearly all of our recommended options result in either large environmental and health benefits or would improve program cost-effectiveness. The exception is the enhanced utilization of the VEC; this recommendation has little direct emissions reductions benefit, but will improve DCO interaction with consumers and assist in building an improved partnership. The additional recommended VEC activities would also collection of data to be used for program evaluation and would allow supplemental testing and repair training. If each of our recommendations involving additional testing, as well as model year exemptions, are adopted for light-duty gasoline vehicles, we expect that the net effect of our recommendations on DCF revenues will be positive; DCFs will lose test fee revenue from exempting two more new model years (~500,000 vehicles). However, we believe this should be more than offset by increased test fee revenue from removing the rolling 20-year-old model year exemption (~19,000 vehicles), and requiring an off-cycle test for failed vehicles (~211,000 vehicles), as well as increased revenue from repairing vehicles that fail the off-cycle test (roughly 84,000 vehicles), and vehicles that would have previously received a conditional pass (27,000 vehicles). Using these figures, and accounting for the change in repair volumes attributable to model year exemptions (~5,100 less), and extensions to 1981 (~10,300 more), we estimate a net decrease in tests of about 270,000 per year, but a net increase in repairs of about 116,000 per year. At an average repair cost of about $400 per vehicle, this should more than offset the decreases in test revenue.

Nevertheless, we acknowledge that the above benefits may not be distributed equitably. For instance, test-only DCFs would indeed observe a net decrease in revenue under this scenario.

The DCO revenue stream would see a corresponding decrease as well. In addition, while there would be significant savings from test fees among motorists with relatively new vehicles, there would be a substantial increase in repair costs for many owners of older and harder-to-repair vehicles (e.g., initial failure and conditional pass vehicles), which are commonly operated by lower-income motorists. And because DCO administrative and oversight costs can vary dramatically depending upon the scope and scale of an option (e.g., number of participants in a repair assistance program), the ultimate financial impacts on DCO will require a refined evaluation in the future. Finally, these conclusions apply only to the precise options "package" described above – to the extent that different combinations of options are ultimately chosen, the overall financial impacts on different program constituencies could vary substantially.

Our combination of recommendations will likely have a slightly negative impact on motorist finances, mostly from testing older vehicles and off-cycle testing of failed vehicles. Consumers may be unhappy with several of our recommendations, particularly removing exemptions for older model years, off-cycle testing for failed vehicles, combined OBDII and ASM testing, and limiting conditional passes and raising the repair cost limit. However, many of these options, particularly combined OBDII and ASM testing, will increase consumer protection, by providing more effective and durable repairs. Overall, we believe that our combined recommendations will have no or a slightly positive effect on social impacts.

Some of our recommended options, especially using remote sensing to target high emitters, and the repair subsidy and early vehicle retirement programs, will be relatively costly to implement. Some of these additional costs can be covered by increased test fee revenue, particularly from removing the rolling model year exemption and off-cycle testing of failed vehicles; however, in net, these options will add costs to the program, and will delay the point at which the program becomes revenue neutral.

Finally, we believe our recommendations will, in concert, improve DCF and motorist compliance with program requirements. Testing older vehicles, off-cycle testing of failed vehicles, limiting the number of conditional passes, and raising the repair cost limit, will all give DCFs and motorists extra incentive to circumvent testing, repair, and registration requirements. However, the repair subsidy and early vehicle requirements will provide motorists incentives to meet program requirements, and either obtain effective repairs or permanently remove their high emitting vehicles from the *Drive Clean* area. Devoting more resources to compliance activities, and more efficient allocation of those resources, should help identify non-compliance and reduce it.

Tables 7-5 through 7-9 summarize the benefits of implementing the recommendations listed above relative to major criteria considered for the analysis.

Table 7-5. *Drive Clean* Options Analysis – Results by Major Criteria

	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL
Environmental Impacts	-	+	+	+	=	=	+	+	+	+	+	+	+	+	=	=	+	+	=	+	+
Health Impacts	-	+	+	+	=	=	+	+	+	+	+	+	+	+	=	=	+	+	=	+	+
Financial Impacts	-	+	-	-	+	-	-	-	?	?	?	?	-	-	-	-	-	-	-	-	-
Cost Effectiveness	+	+	+	?	+	=	+	+	+	+	+	+	=	+	=	=	+	+	?	?	+
Social Impacts	+	-	-	-	+	=	-	-	?	-	+	+	+	=	=	=	+	+	+	+	=
Program Impacts	+	+	?	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Compliance Impacts	=	-	-	+	=	=	+	+	-	-	+	+	?	=	=	=	+	+	=	+	+

Table 7-6. Expanded Detail – Financial Impacts

	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL
Financial Impacts	**-**	**+**	**-**	**-**	**+**	**-**	**-**	**-**	**?**	**?**	**?**	**?**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
•DCF Financial Impact	-	+	+	-	=	=	+	+	+	+	-	+	-	-	=	=	+	+	=	=	+
•Program Financial Impact	-	+	=	=	=	-	-	-	=	=	-	-	-	=	-	-	-	-	-	-	-
•Motorist Financial Impact	+	-	-	-	+	=	-	-	-	-	+	+	+	=	=	=	=	=	=	=	-

Table 7-7. Expanded Detail – Social Impacts

	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL
Social Impacts	**+**	**-**	**-**	**-**	**+**	**=**	**-**	**-**	**?**	**-**	**+**	**+**	**+**	**=**	**=**	**=**	**+**	**+**	**+**	**+**	**+**
•Customer Acceptance	+	-	-	-	+	=	-	-	-	-	+	+	+	=	=	=	+	+	+	+	-
•Consumer Protection	=	=	+	+	+	+	=	+	-	-	+	=	+	=	+	+	+	=	+	+	+
•Equity	-	-	=	-	+	=	-	-	+	+	+	+	=	=	=	=	+	+	=	=	+

Table 7-8. Expanded Detail –Program Impacts

	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL
Program Impacts	**+**	**+**	**?**	**-**	**+**	**-**	**-**	**-**	**+**	**+**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
•Test Fee Revenue	-	+	+	=	-	=	+	+	+	=	=	=	=	=	=	=	=	+	=	+	+
•Program Logistics	+	+	-	-	+	-	-	-	+	+	-	-	-	-	=	-	-	-	-	-	-

Table 7-9. Expanded Detail – Environmental Impact

	Exempt 2 additional new Mys in LD Program	End 20 Year Exemption in LD Program	Require Annual Testing for Previous Initial Fails	Implement LDGV OBDII/ ASM testing	Ensure ASM Testing at Operating Temperature	Perform a LD Diesel Test Pilot Program	Target High Emitters - Smog Patrol	Target High Emitters - RSD	Limit # of Conditional Passes Granted	Increase RCL to Reduce Waivers	Implement a Vehicle Early Retirement Program	Low-Income Repair Assistance Program	Improve LD Repair Effectiveness	Establish a HD Chip Reflash Program	Monitor Effectiveness of HD OBDII Systems	Conduct Pilot Study on HD NOx and PM Testing	Prevent Test & Repair Fraud	Prevent Registration Fraud	Expand Use of VEC	Expand use of Smog Patrol	OVERALL
Environmental Impacts	**-**	**+**	**+**	**+**	**=**	**=**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**=**	**=**	**+**	**+**	**=**	**+**	**+**
VOC	-	+	+	+	=	=	+	+	+	+	+	+	+		=	=	+	+	=	+	+
CO	-	+	+	+	=	=	+	+	+	+	+	+	+		=	=	+	+	=	+	+
NOx	-	+	+	+	=	=	+	+	+	+	+	+	+	+	=	=	+	+	=	+	+
PM	=	=	=	=	=	=	+	=	=	=	=	=	+		=	=	=	=	=	+	+